Age and Growth of Rio Grande Silvery Minnow

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THE ACADEMY OF NATURAL SCIENCES
– Philadelphia –

The Academy of Natural Sciences

- Natural history museum, systematic and ecological research institution located in Philadelphia
- Founded 1812
- Comprehensive fish collection of international scope
  - Many types, including Western US
  - E.D. Cope, 19th Century scientist at Academy

Who are we?

- **Richard Horwitz** (Ph.D.), Ruth Patrick Chair of Environmental Research and Fisheries Section Leader
- Numerous projects on ecology of freshwater fishes
- Age analyses
  - Since mid-1980's
  - Contaminant analyses: Age of fish to model concentration-age relationships
  - Life history
    - Early growth of American shad
    - Growth and movements of American eel after entering freshwater
  - Human impacts
    - Effects of pesticide spraying on short-term growth rates
    - Effects of point sources on growth rates of fish
- **David Keller** (MS, 8 years experience)
  - Experience on a number of studies
  - Age and growth of catfish in Delaware River catfish (PA-NJ)
- **Paul Overbeck** (25 years experience)
  - Experience on a number of studies

Outline

- Introduction to study
- Introduction to otolith analyses
- Methods
  - Otoliths
  - Scales
- Analyses of Age-0 recent fish
- Analyses of age structure of recent population
- Analyses of age classes of 1874 fish

Aging Study

- Compare otolith and scales for aging
- Make best estimates of ages
- Determine reliability
- Determine age-at-length
- Combine with length distribution to get age distribution
- For Age-0 fish
  - Estimate age in days
  - Estimate daily growth rate

Basic Design

- Recent fish
  - Fall (October-November) 2009
  - Spring (April-May) 2010
  - 4 fish from each 10-mm size class from x 3 stations x 2 seasons =150 total fish
  - Sampling designed to supply fish from size classes; uses a small proportion of smaller fish and most larger fish caught
- Historical fish
  - August 1874 (USNM)

Otoliths

- Three pairs of bones in head used for balance
- Grows regularly with age, laying down alternate dark and light bands (more and less organic material)
- Daily layers most visible in young fish
- Concentration of very narrow dark bands in winter or spring forms annual mark (annulus)

What are Otoliths?

- Otoliths and sacs (vestibules)
  - Sagitta (saccular)
  - Lapillus (utricular)
  - Astericus (lagenar)
- Lie at top of brain
- Used lapillus
- Otolith size highly correlated with fish size

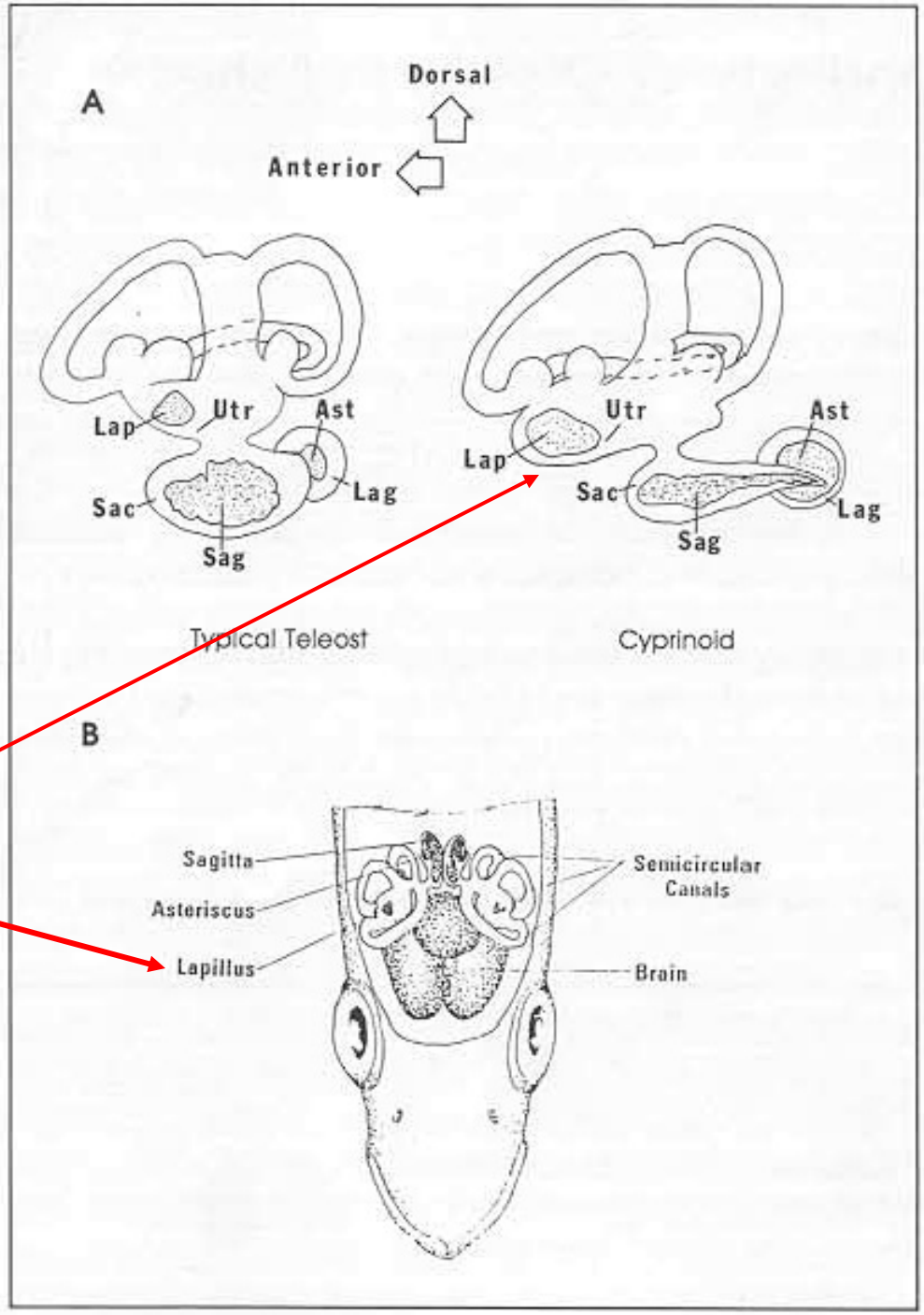
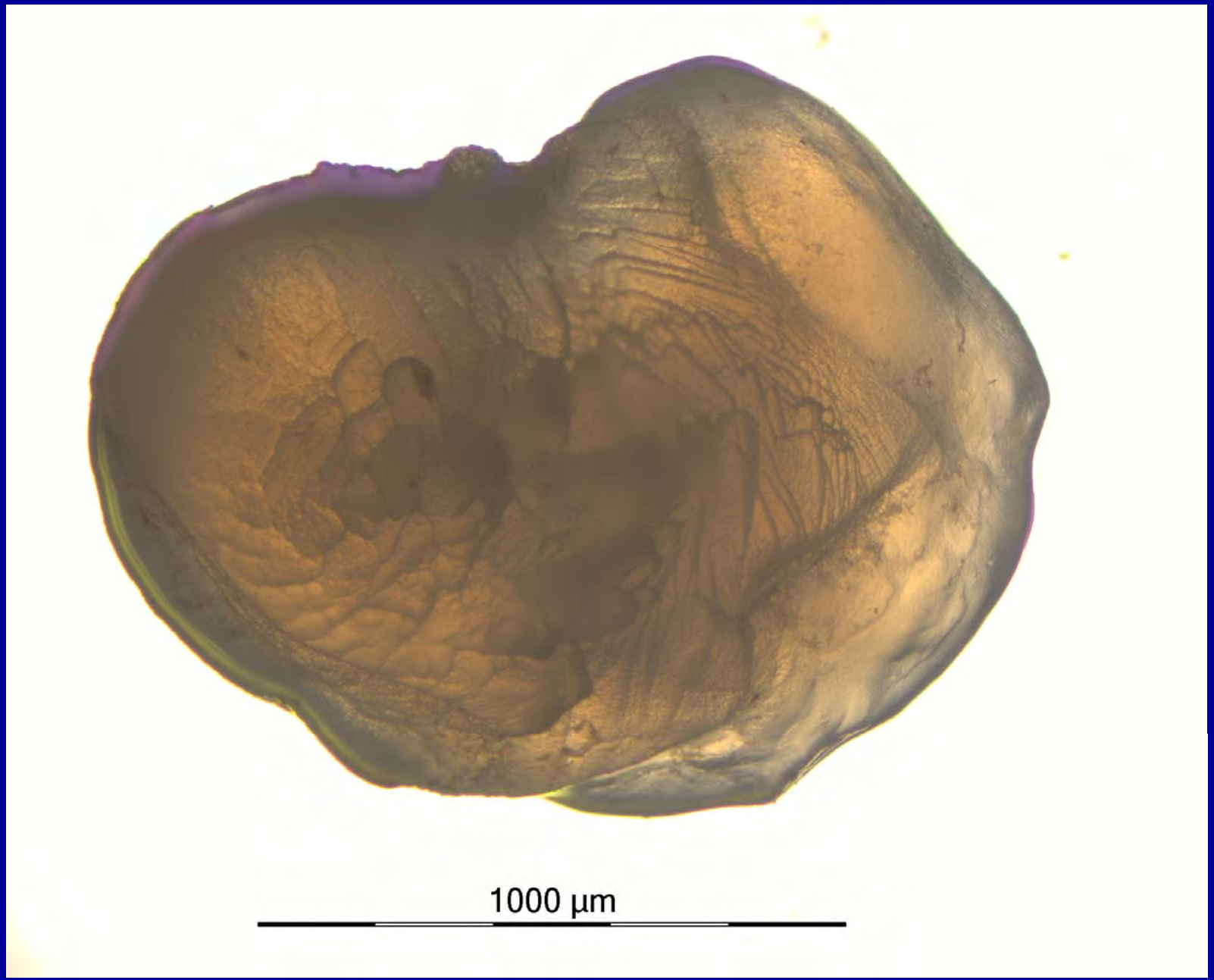


Figure from Secor, D. Manual of otolith analysis

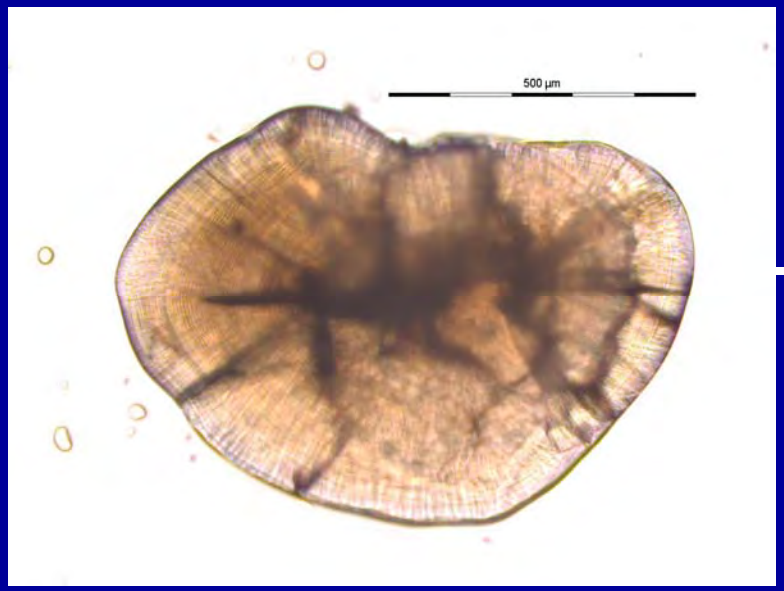

Chain
pickerel

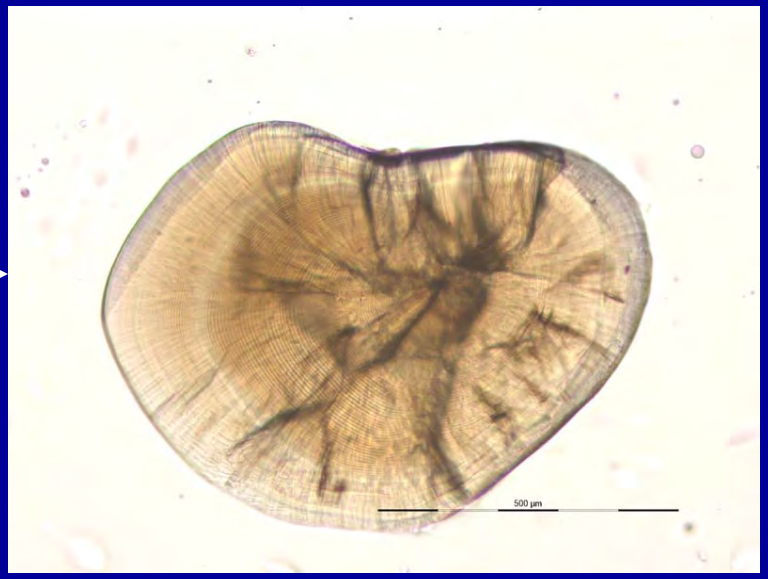
Whole Otolith of RGSM



Methods: Age Determination using Otoliths

- Removed, embedded, and polished to view rings (standard techniques, e.g., Secor et al. 1991)
- Viewed in oil under 3.5X-28X power and took multiple digital images

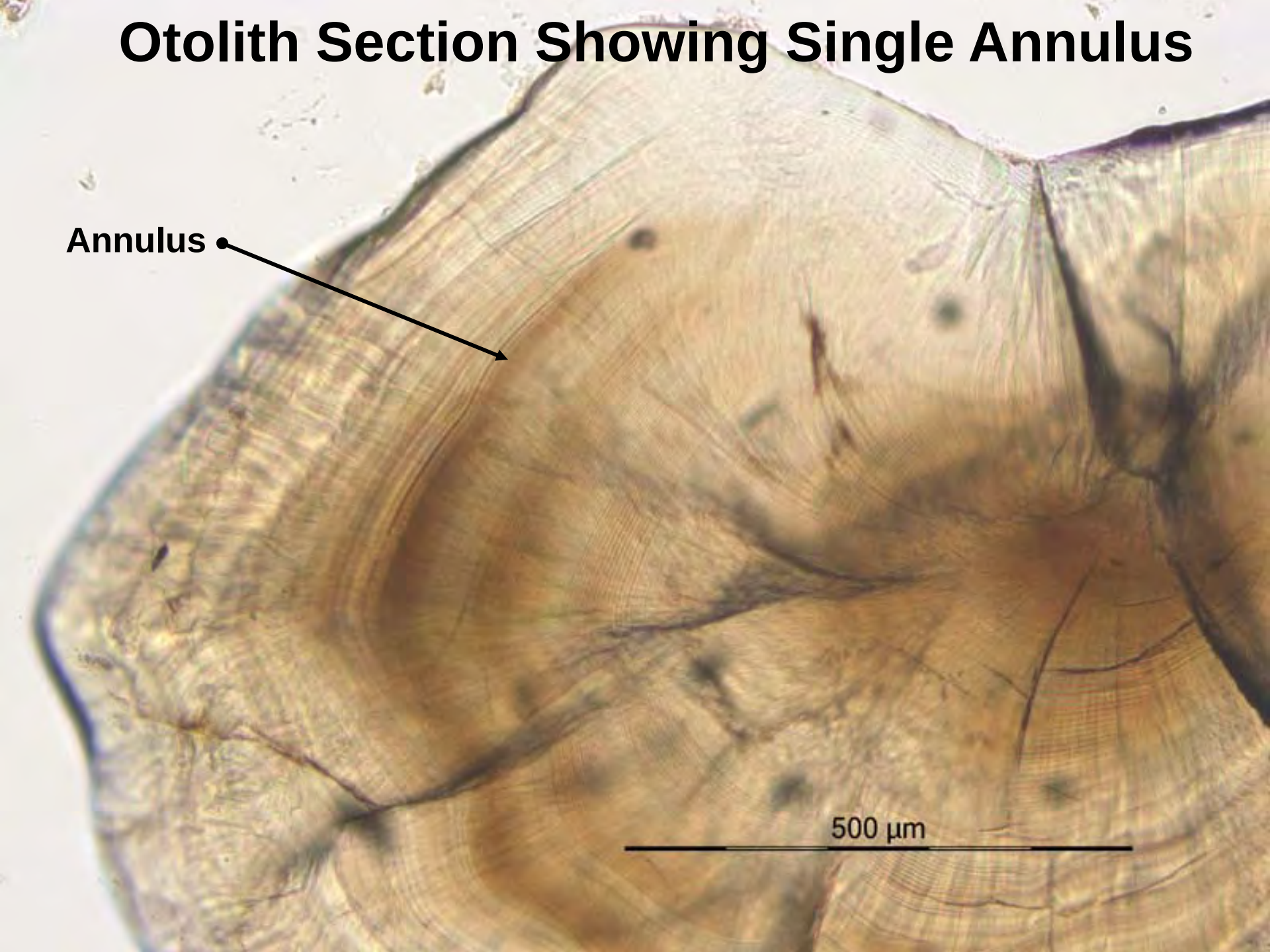




Methods: Age Determination using Otoliths

- Aged fish
  - Aged to year
  - Age-0 fish aged to day
- Annulus criteria
  - Dark band of narrowly spaced rings
  - Preceded and followed by more widely spaced rings
  - Did not use size of otolith, size of fish, station, etc.
- Age (in years) determined independently by two readers
- Disagreement reconciled during joint reading

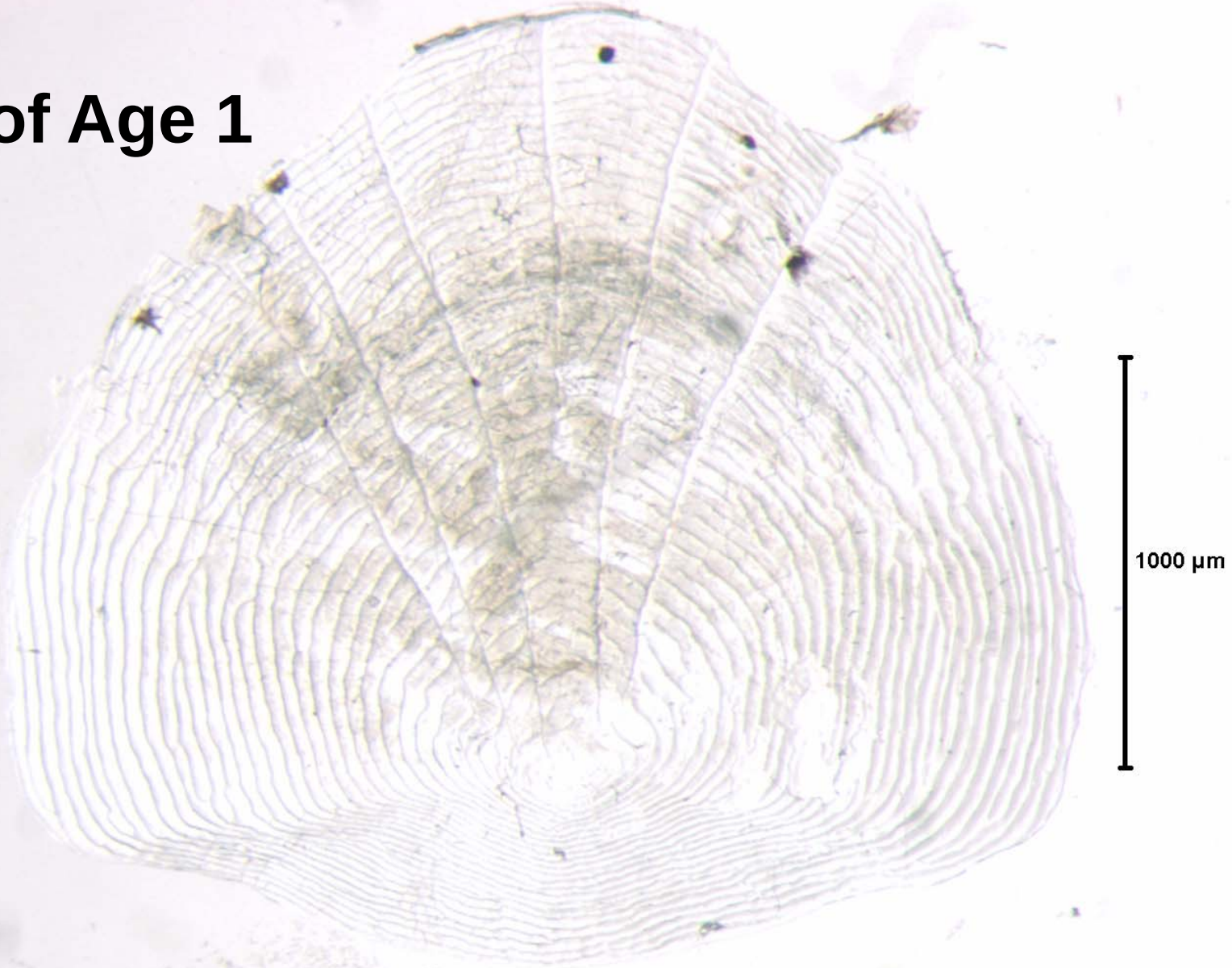
Otolith Section Showing Single Annulus

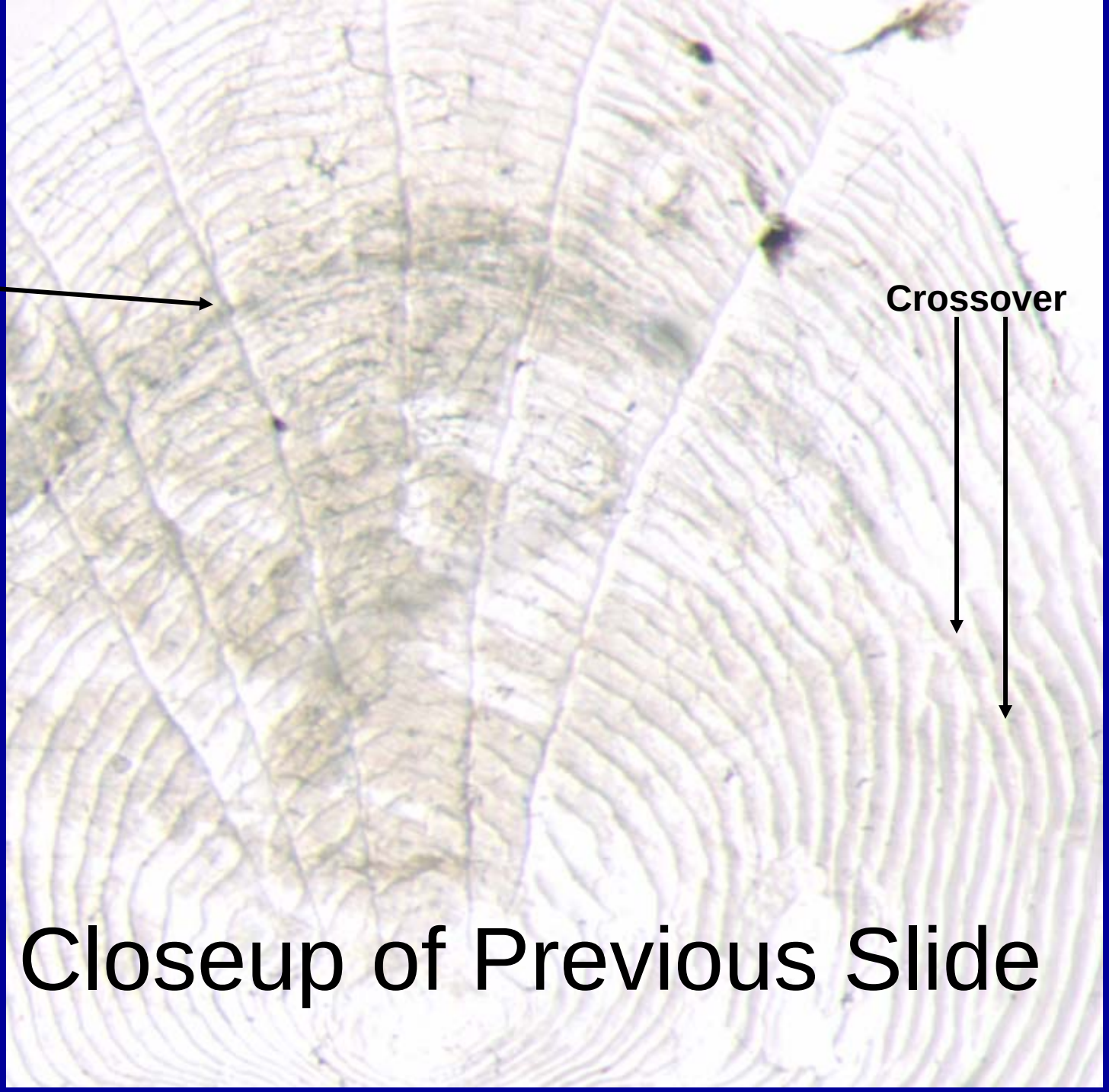


Age Determination using Scales

- Use rings for aging, but these not daily
- Annuli defined by patterns of rings
- Validation of scale ages for other species have found problems in defining annuli, leading to development of criteria to avoid “false annuli”
- Scales often difficult to correctly age for older fish

Scale of Age 1
RGSM





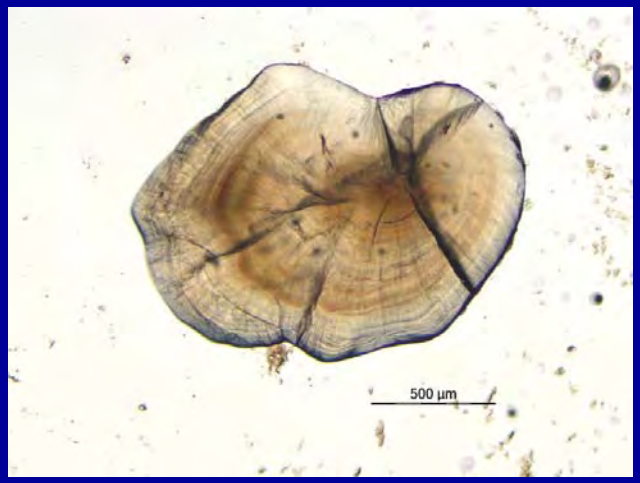
Closeup of Previous Slide

Project Methods: Scale Analyses

- Removed and mounted between two glass slides
- Viewed under 31.25X power and digitally imaged
- Annulus criteria
  - Primary: Crowded circuli, cross-over
  - Secondary: New radii
  - Did not use size of scales, size of fish, station, etc.
- Age (in years) determined independently by two readers
- Disagreement reconciled during joint reading

Methods: Final Age Determination

- Disagreement between scales and otoliths reconciled
- Analyses of precision
- Percent agreement between readers on otolith and scales
- Percent agreement between final otolith age and final scale age

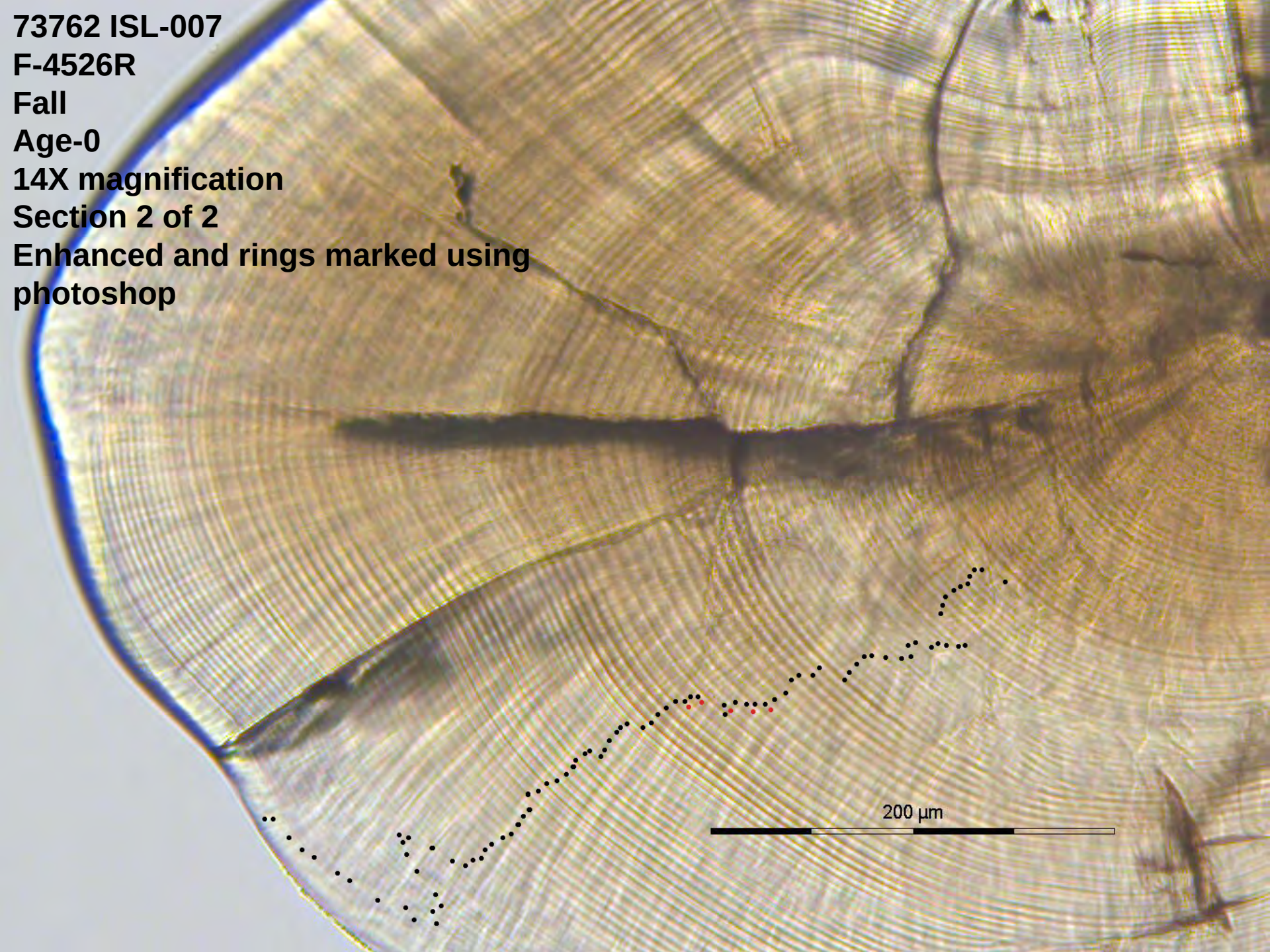


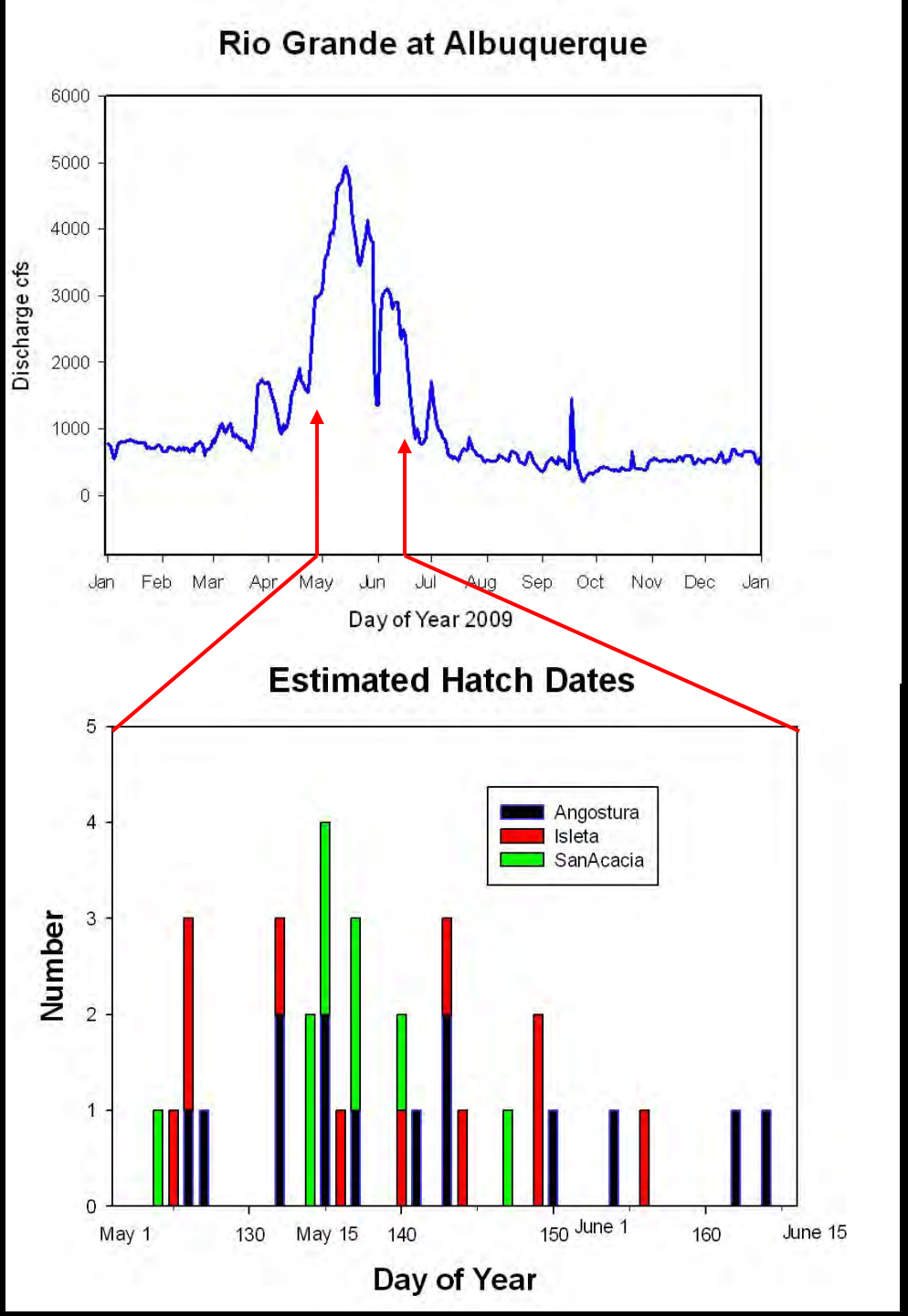
+

→ Otolith-Scale Age

Analyses of Age 0 Fish

- All from Fall, 2009
- Estimated ages in days from daily rings
  - Daily and subdaily rings sometimes difficult to distinguish
  - Does not affect age class (years), but affects age in days
- Estimated hatch dates
- Estimated average daily growth rates
- Validation of daily ages of known-age Plains minnow has been done


73762 ISL-007
F-4526R
Fall
Age-0
14X magnification
Section 2 of 2
Enhanced and rings marked using photoshop
200 µm


Rio Grande at Albuquerque
Discharge cfs
6000
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Day of Year 2009
Estimated Hatch Dates
Number
5
4
3
2
1
0
Angostura
Isleta
SanAcacia
May 1
130
May 15
140
150
June 1
160
June 15
Day of Year

Average Growth Rates of Age 0 RGSM, from Fall, 2009 samples

Reach	*N*	FSL[a] (mm)	Daily Growth Rate (mm dy^{-1})b	
		Mean	Mean	Standard error
Angostura	14	44	0.30	0.020
Isleta	11	43	0.29	0.017
San Acacia	8	43	0.28	0.011

(a) Equal numbers of fish per 10 mm size class were sacrificed for age and growth studies

(b) Assume SL = 3.0 mm at hatching

No significant difference among stations

Examples of Otoliths from other Species

Smallmouth bass

Size of otolith highly correlated with size of fish

Smallmouth Bass

Similar size of otoliths of fish of different age reflect different growth rates (type of waterbody, etc.)

Shallow, warm, enriched impoundment

Coldwater river

Results: Agreement between Ages

- Both readers obtained only three ages 0-2 (fall) and 1-3(spring)
- Differences usually of 1 year

			Percent Agreement			
		N	Reader 1 - Reader 2	Reader 1	Reader 2	Final
Fall 2009	Otolith	83	86%			
	Scale	83	78%			
	Otolith-Scale	83		82%	78%	92%
Spring 2010	Otolith	75	96%			
	Scale	75	89%			
	Otolith-Scale	75		92%	88%	89%

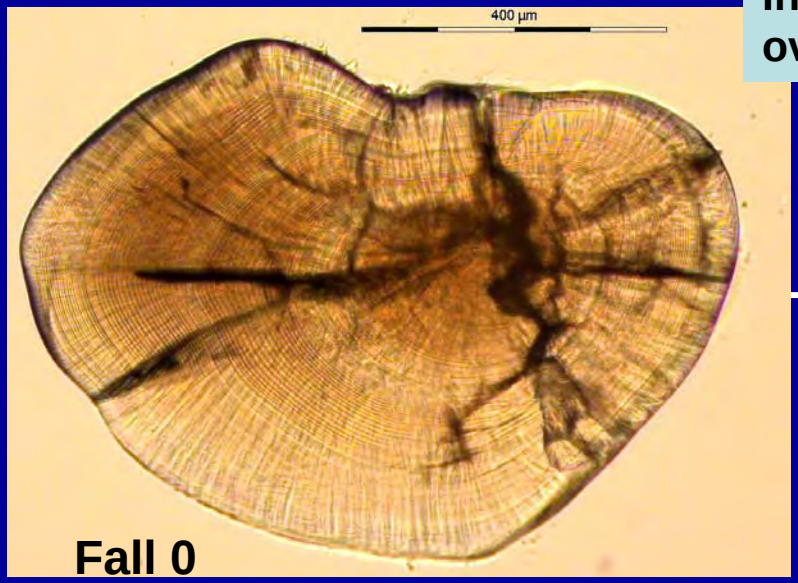
Comparison of Otoliths and Scales

- Each structure, between readers
  - High agreement on age 0 fall, age 1 spring
  - Lower agreement higher ages
- Among structures
  - No consistent difference between otolith and scale ages
  - Otoliths more reliable
    - More information, especially for determining first annulus
  - Unable to develop completely reliable scale criteria
    - Inclusive criteria would over-age some fish
    - Strict criteria would under-age some fish
    - Best criteria had relatively strict criteria (well-defined crossover on at least one side, usually some crossover on other side, crowding of circuli)

Age Classes in Recent Specimens

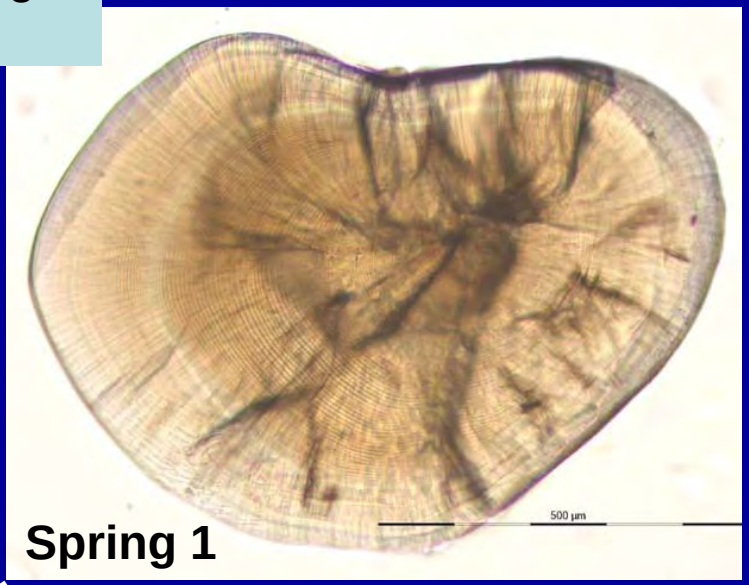
- Show otolith sections from different age classes
- Annulus formed in late spring
- Age changes before annulus forms, so spring fish will show same number of annuli as fish one age younger in fall

Increment age over winter



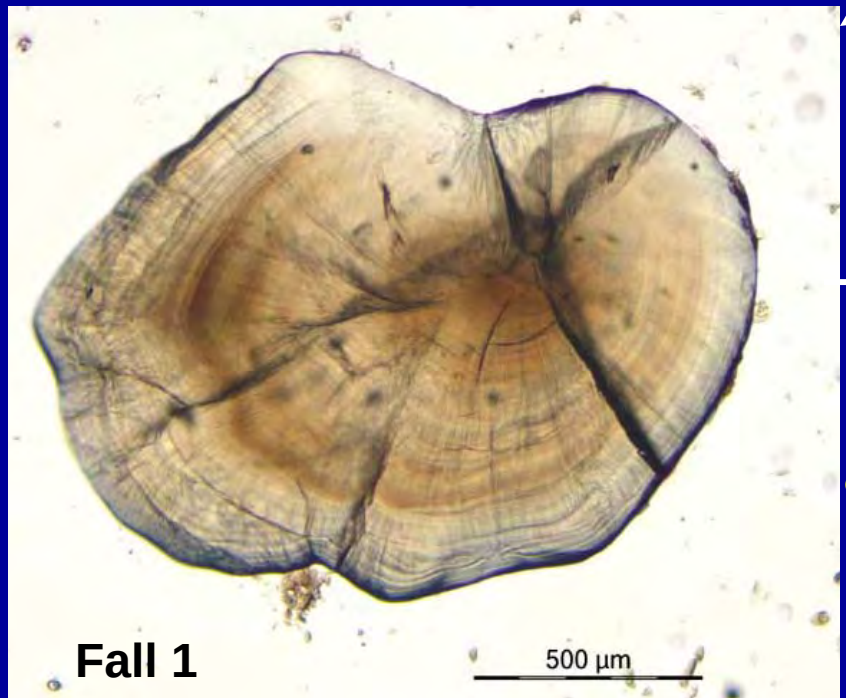
Fall 0

No annuli



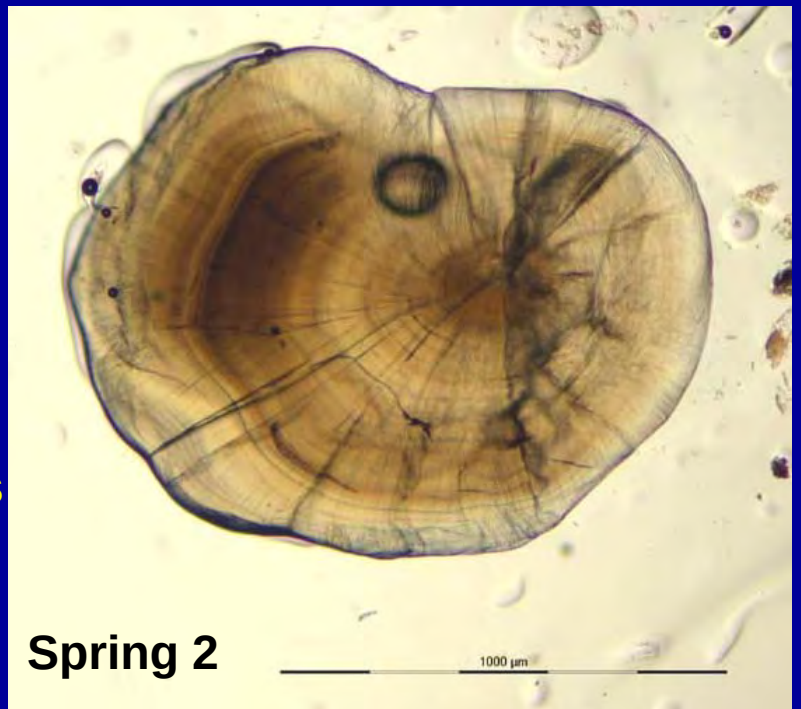
Spring 1

Note differences in scale bar



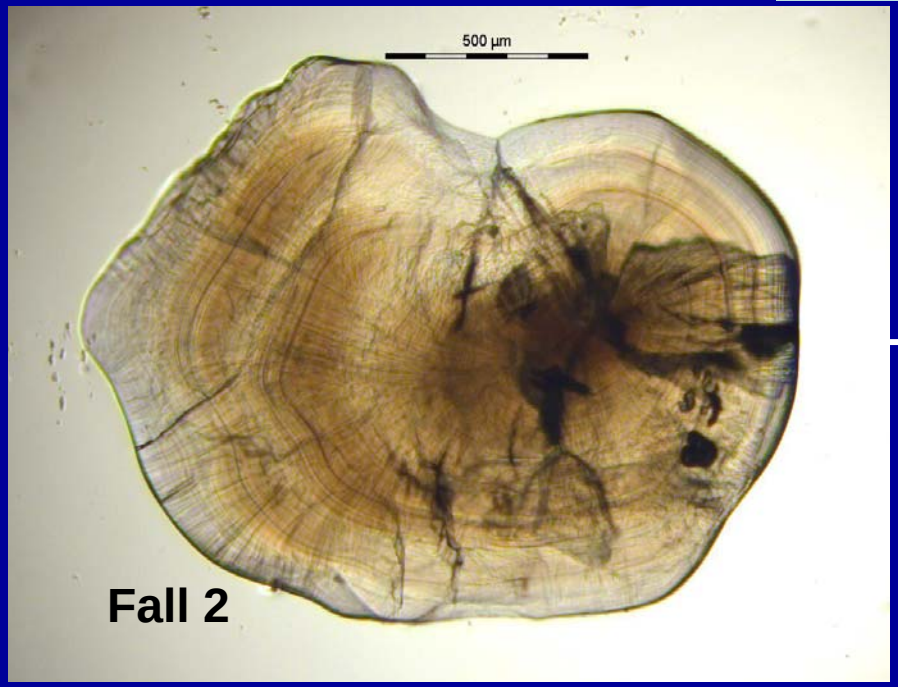
Fall 1

One annulus



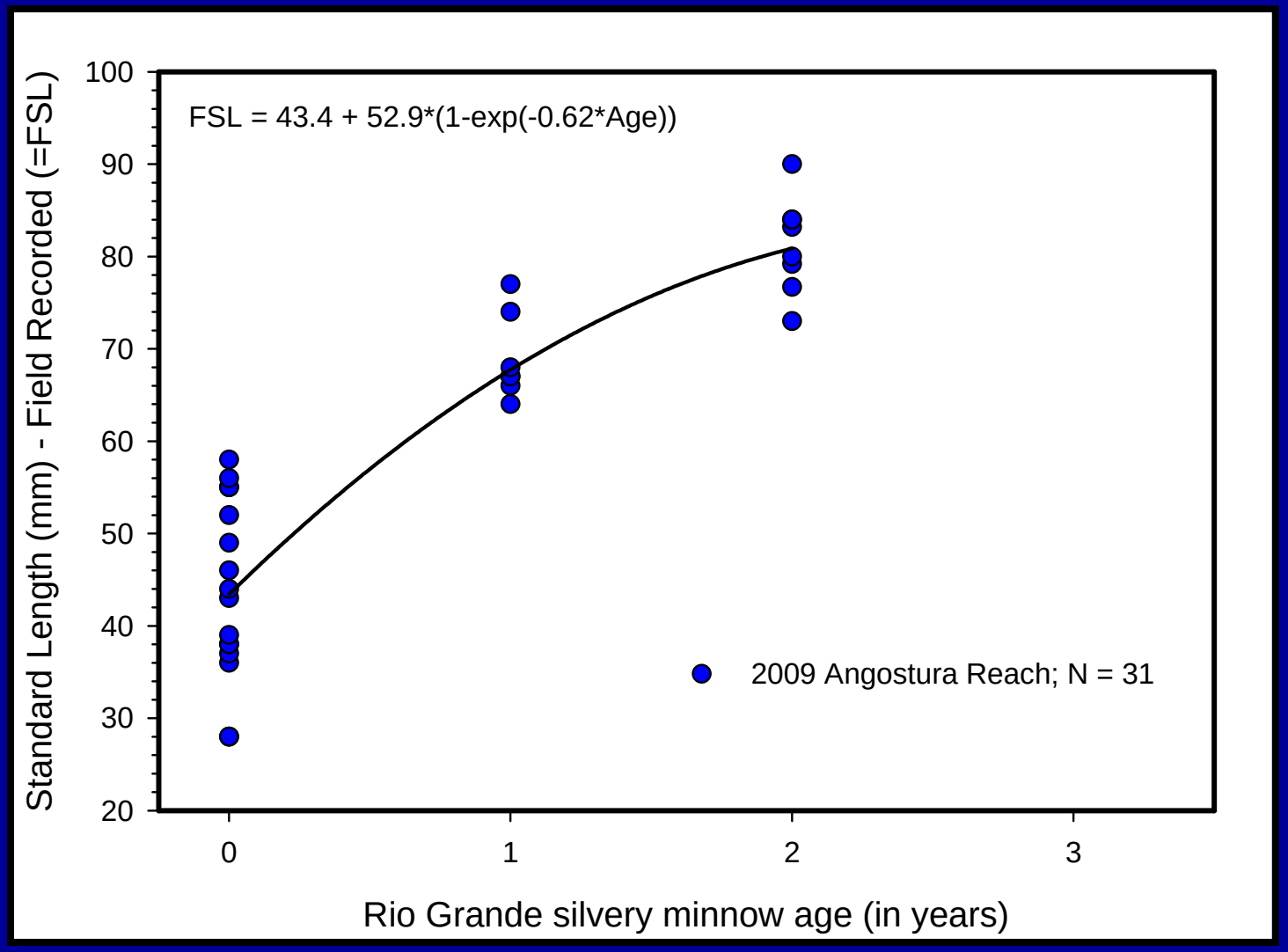
Spring 2

Increment age over winter

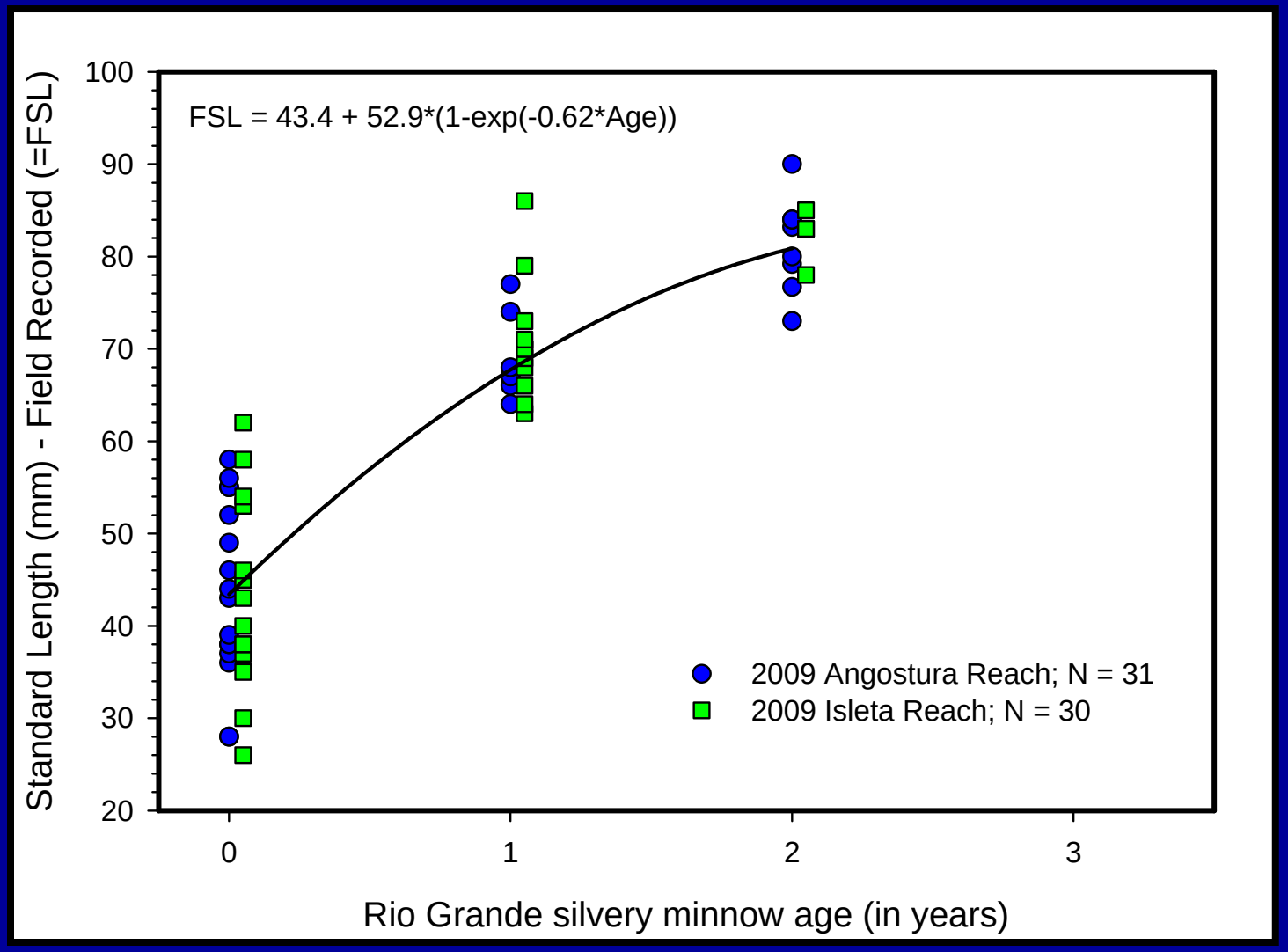


Two annuli

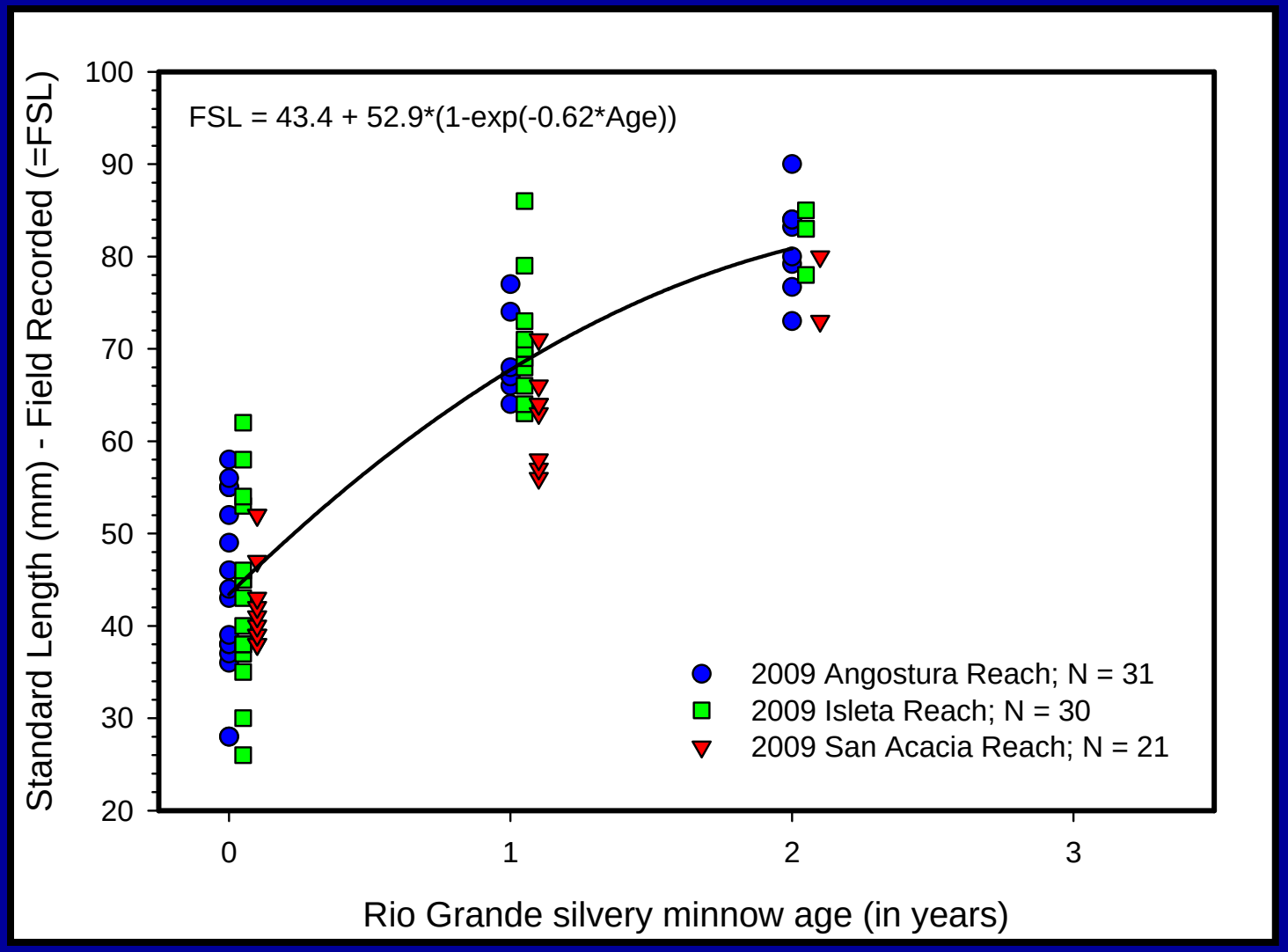
Rio Grande silvery minnow
(Oct-Nov 2009)



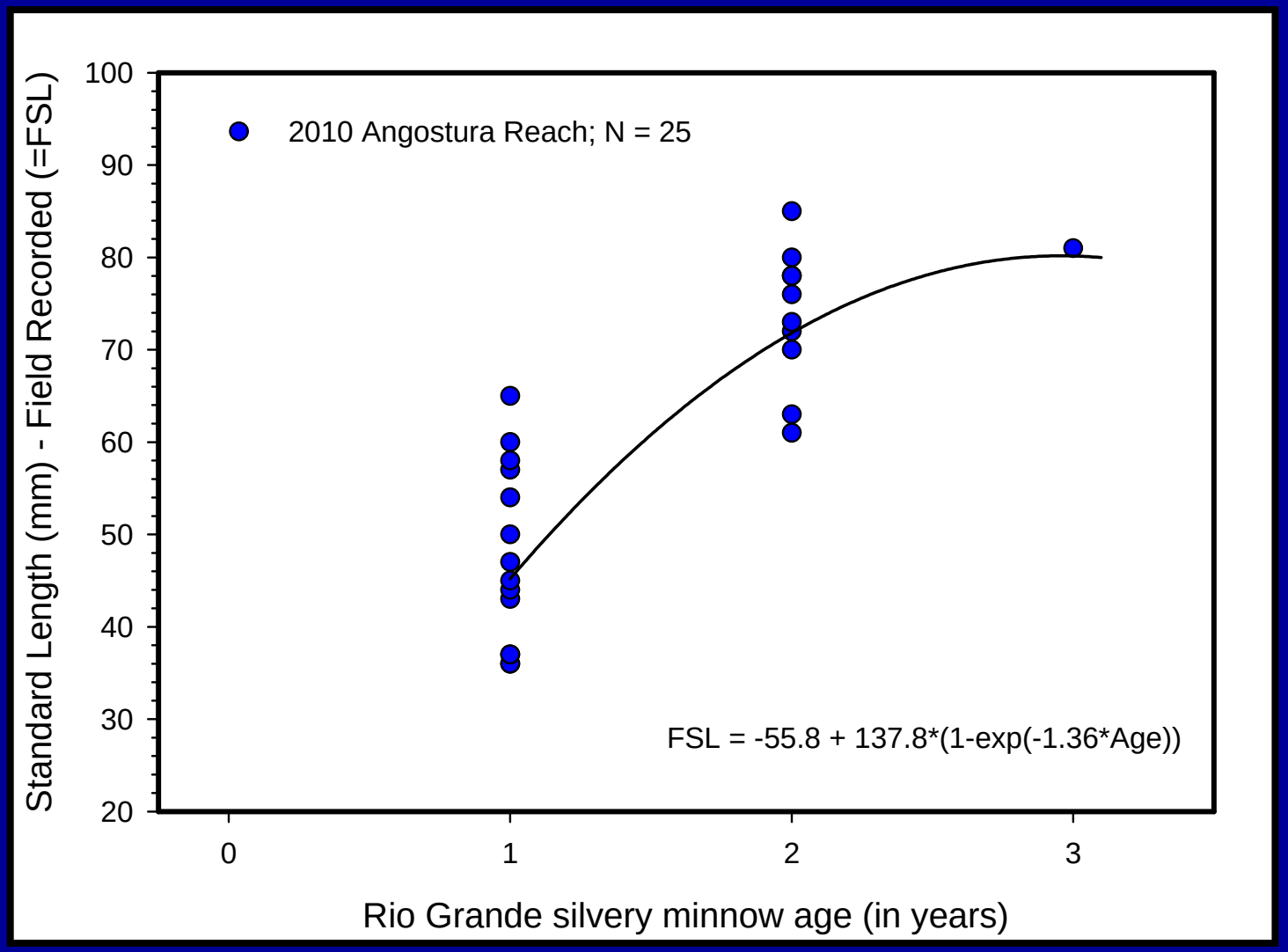
Rio Grande silvery minnow
(Oct-Nov 2009)



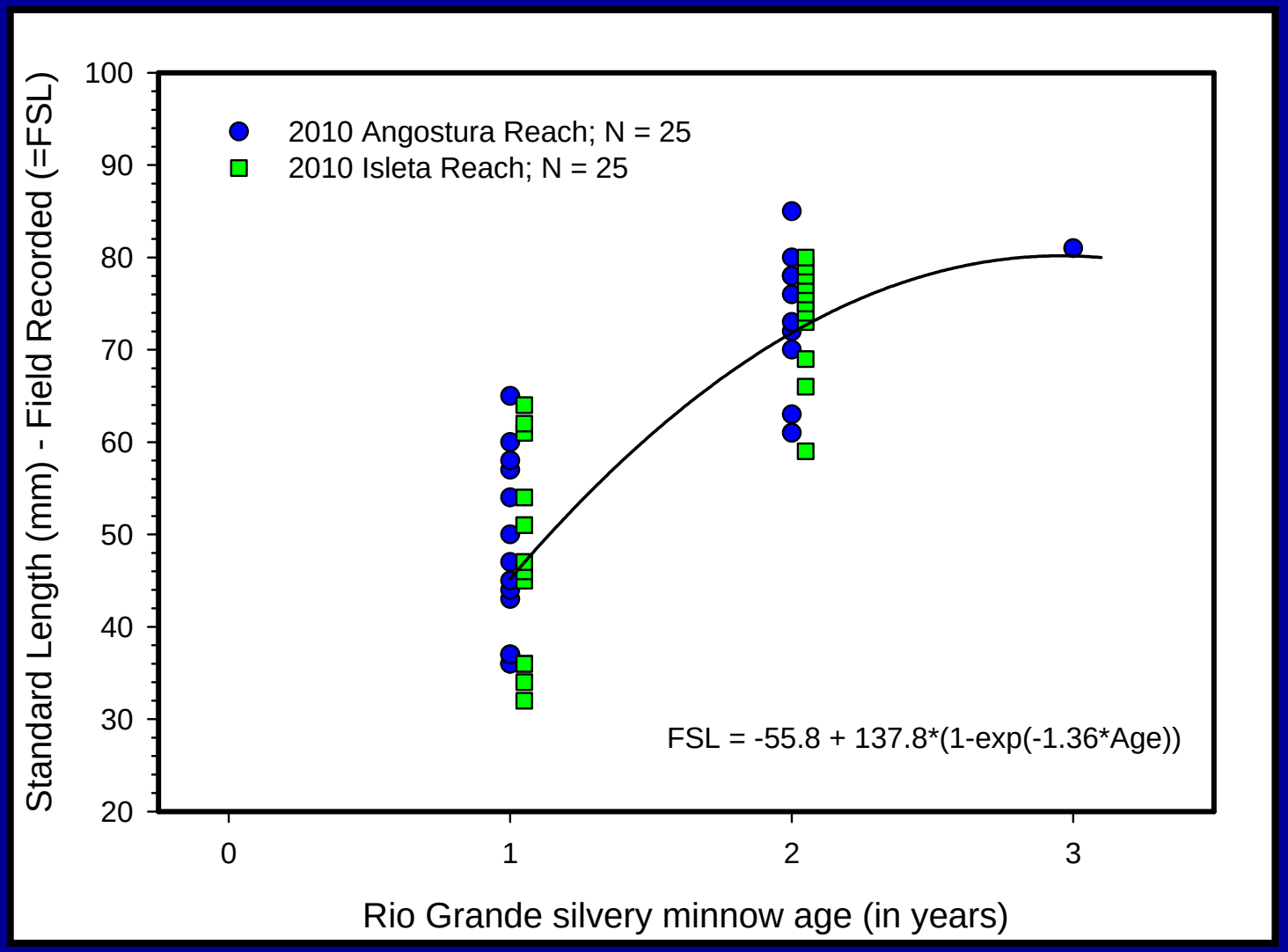
Rio Grande silvery minnow
(Oct-Nov 2009)



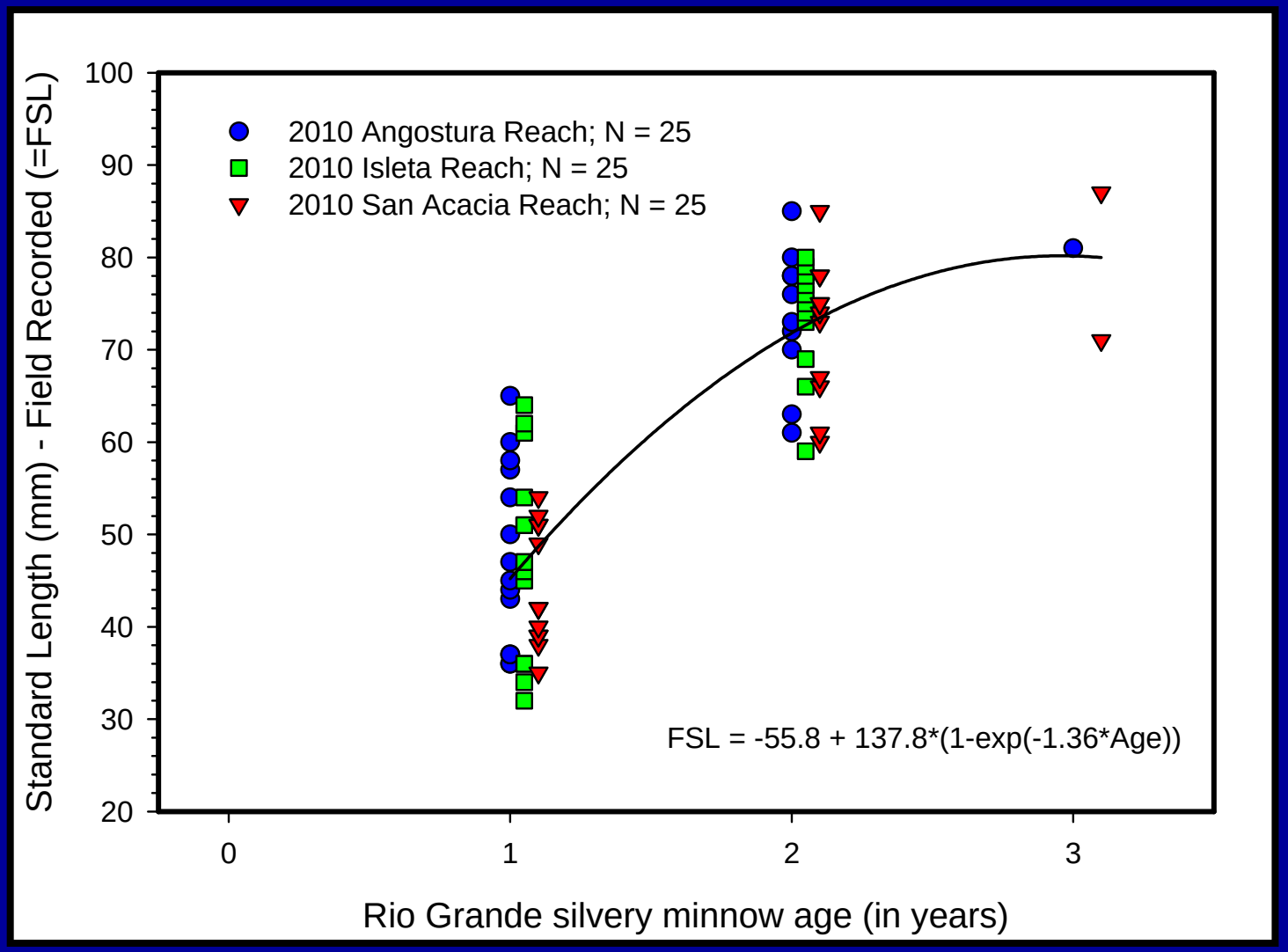
Rio Grande silvery minnow
(Apr-May 2010)



Rio Grande silvery minnow
(Apr-May 2010)



Rio Grande silvery minnow
(Apr-May 2010)



Proportion of Fish in Each 10 mm size class

Size class	*N*	Size range of minority age	Fall 2009 0	1	2	3
20-50	31	-	1.00	-	-	-
50-60	13	56-58	0.62	0.38	-	-
60-70	15	62	0.07	0.93	-	-
70-80	13[a]	73-79	-	0.31	0.69	-
80-90	9	86	-	0.11	0.89	-
>90	1	-	-	-	1.00	-
				Spring 2010		
30-50	24	-	-	1.00	-	-
50-60	12	59	-	0.92	0.08	-
60-70	13	60-65	-	0.38	0.62	-
70-80	20	71	-	-	0.95	0.05
80-90	6	81-87	-	-	0.67	0.33

(a) Does not include one unassignable specimen

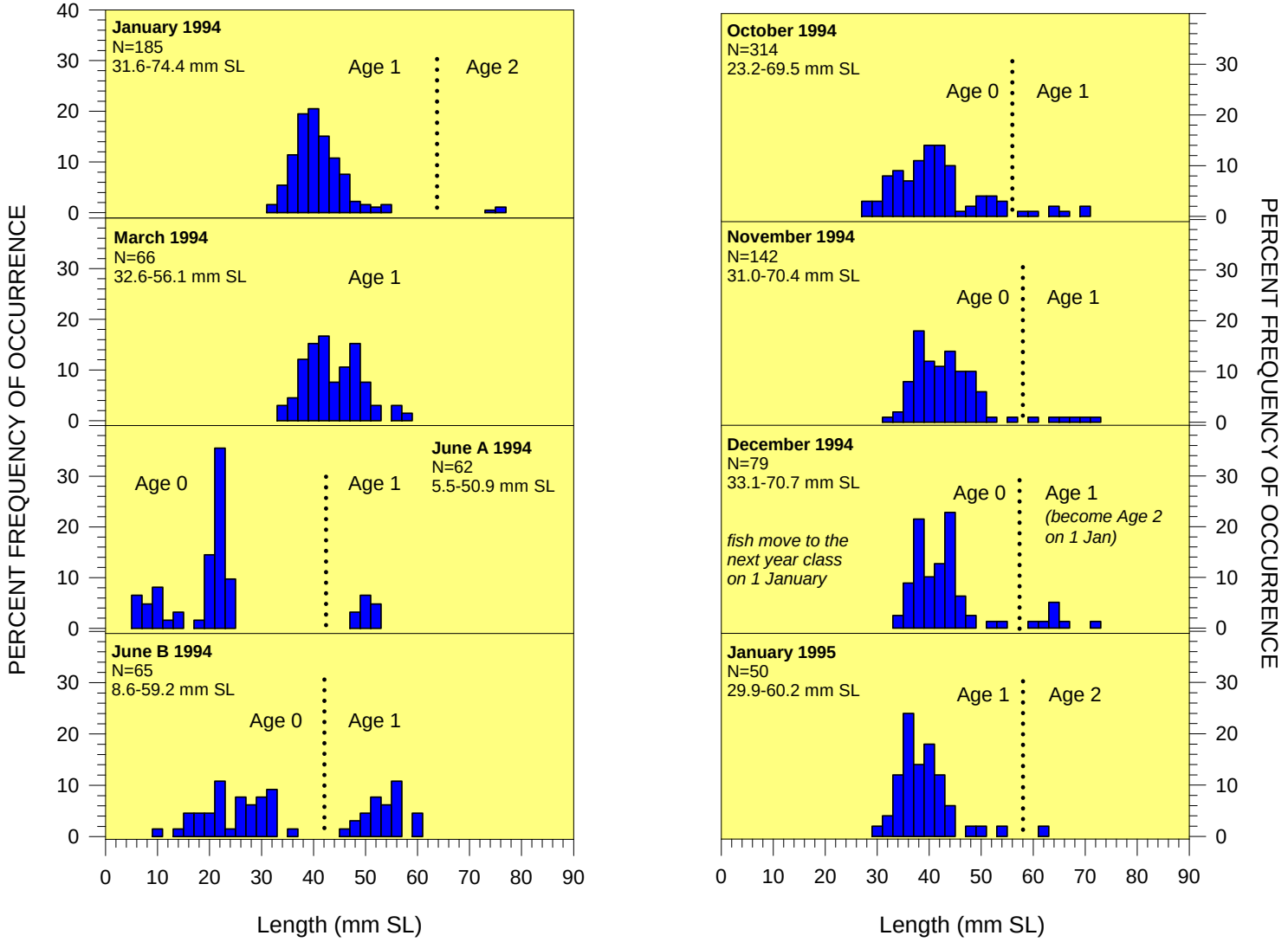
Age Class Structure

- Use all Oct-Nov, 2009, RGSM (Population monitoring and population estimation studies)
- Use all April-May, 2010, RGSM (Population monitoring studies)
- Based on 10 mm size groups
- Post hoc use of size-age would give higher % of dominant age classes

	Fall	Spring
Total Number	10897	1349
Age		
0	88.7%	0.0%
1	10.8%	91.8%
2	0.5%	8.0%
3	0.0%	0.2%

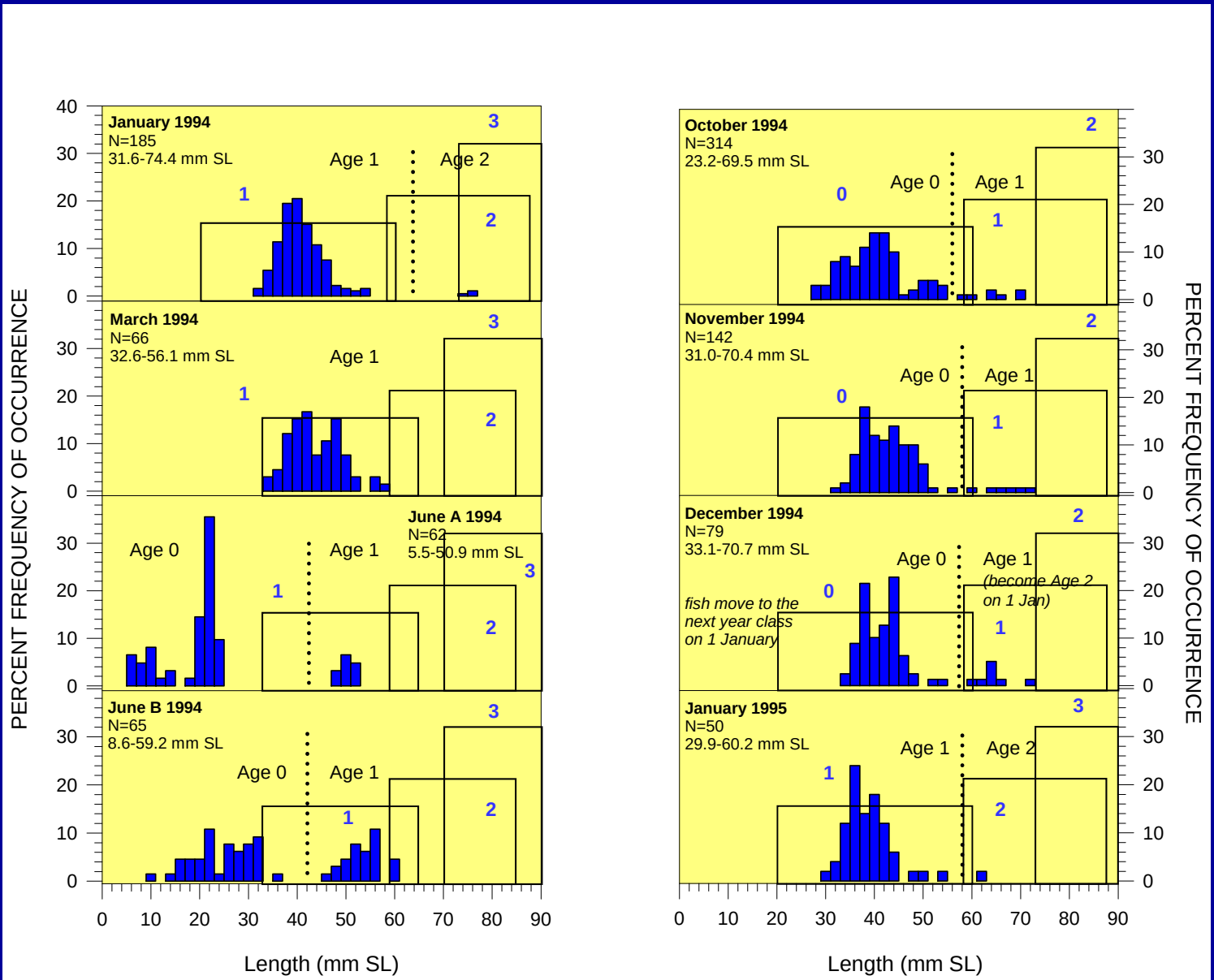
Rio Grande silvery minnow length frequency histograms

(1994 monthly samples - RGSM Recovery Plan)

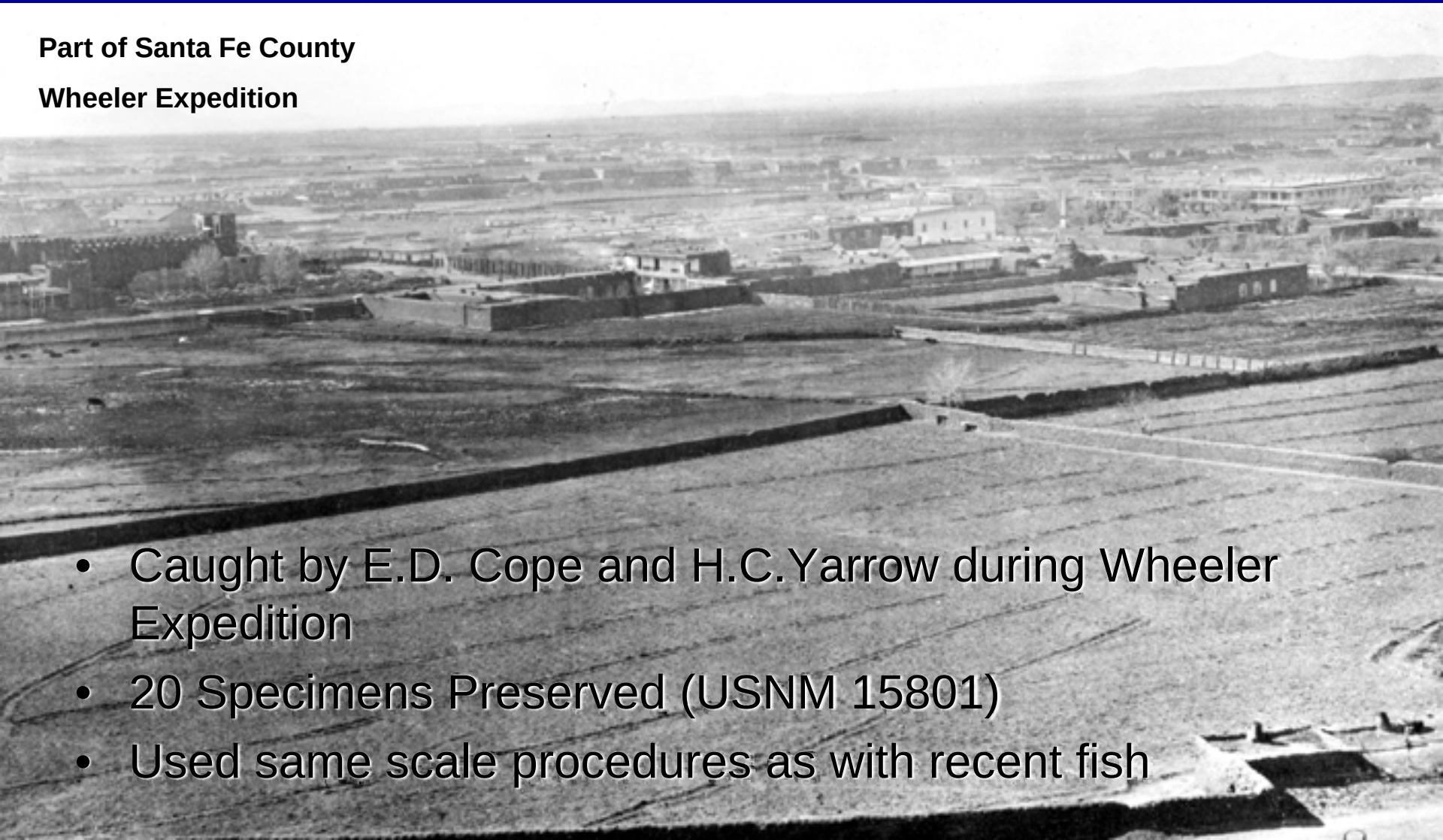


Rio Grande silvery minnow length frequency histograms

(1994 monthly samples - RGSM Recovery Plan)



Historic Samples: August, 1874, at San Ildefonso

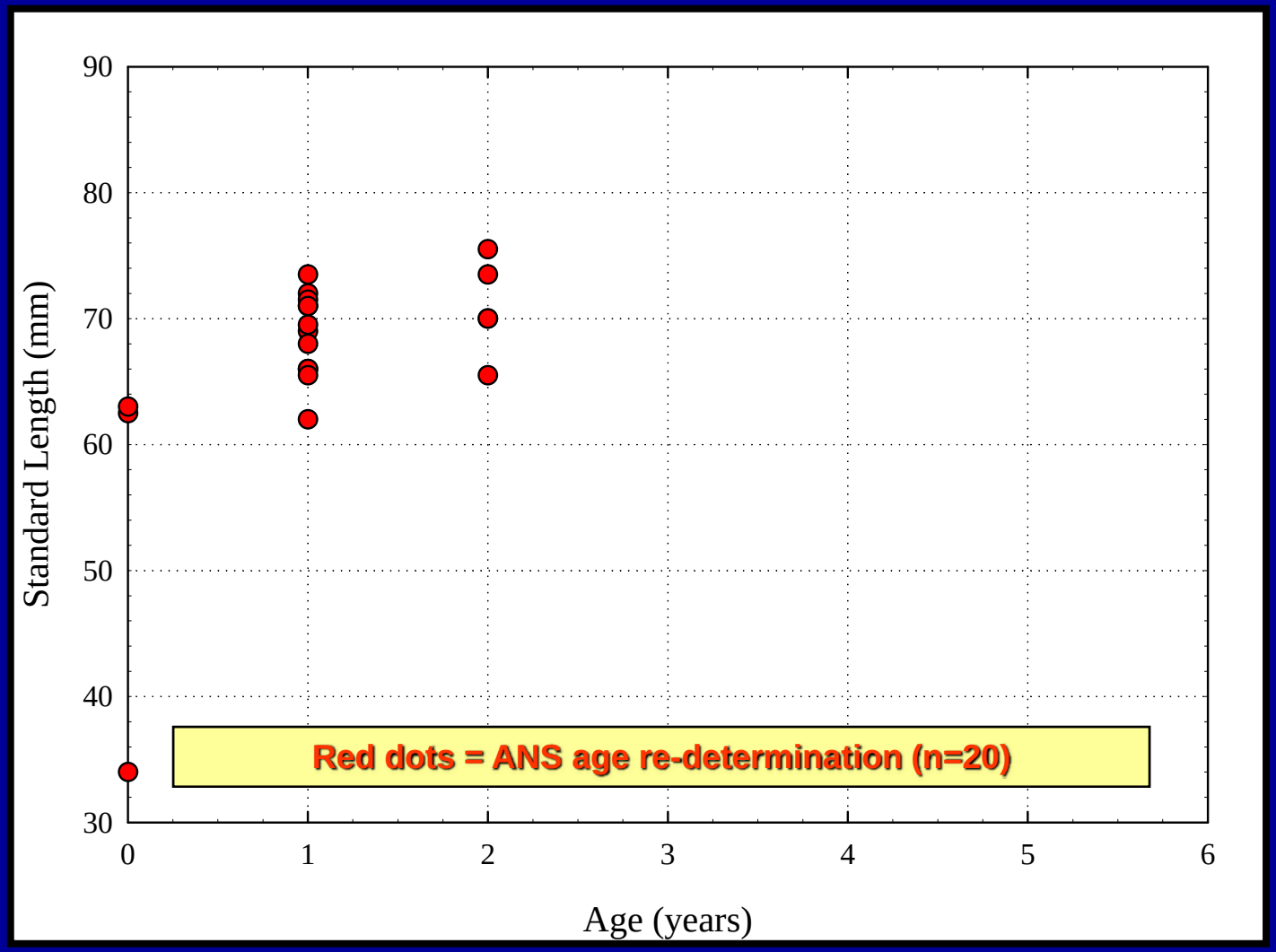


- Caught by E.D. Cope and H.C.Yarrow during Wheeler Expedition
- 20 Specimens Preserved (USNM 15801)
- Used same scale procedures as with recent fish


15801
FISH #11
SL=66.0 MM


MITUTOYO
JAPAN
15801
FISH #1
SL=
75.5MM

ANS Age-Length of USNM RGSM



ANS Age-Length of USNM RGSM

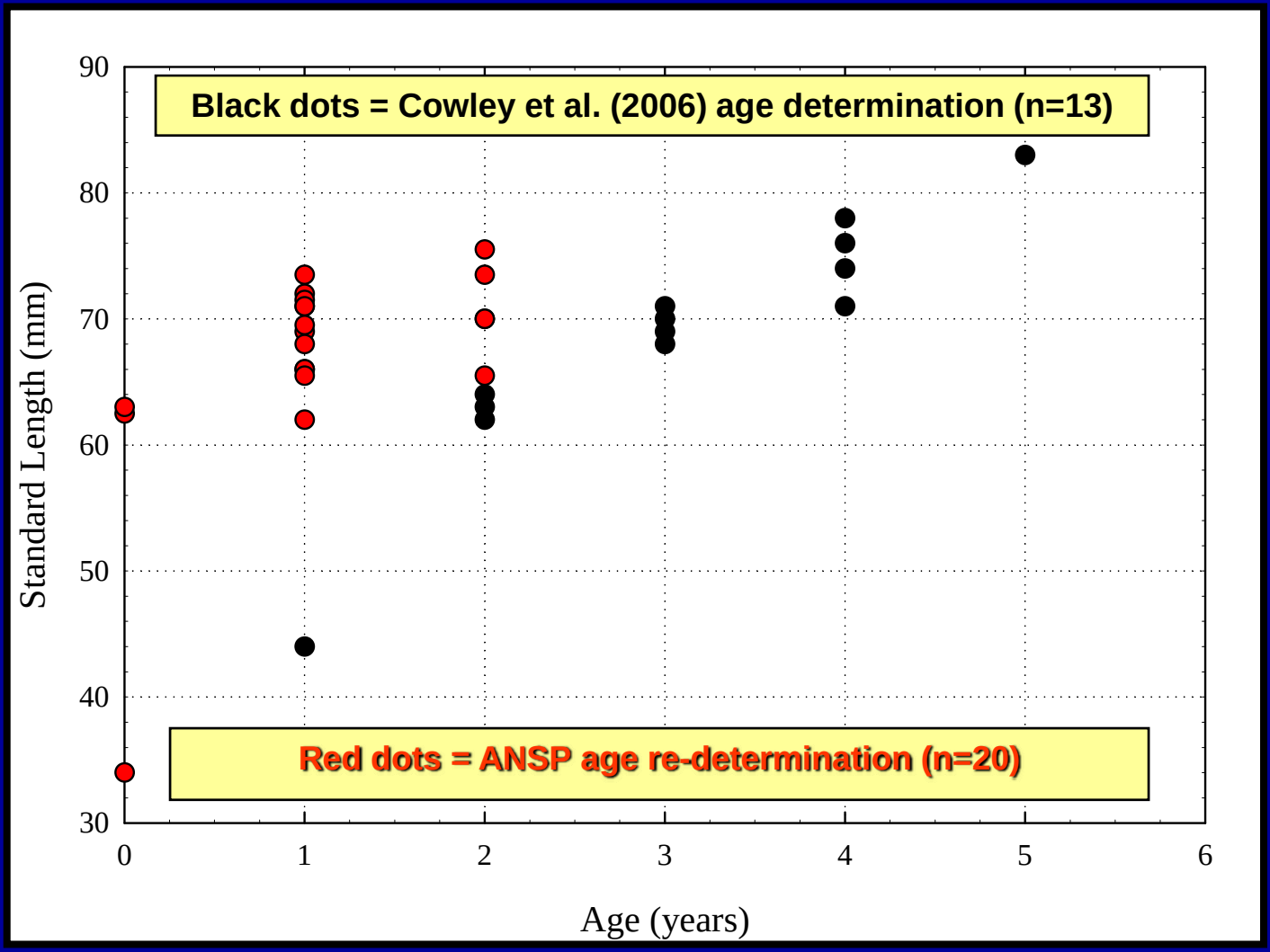


Figure 2. Age inferred from annuli on scales from 13 specimens of *H. amarus* collected in 1874 from the Rio Grande at San Ildefonso (Cowley et al. 2006).

Results

Of 20 USNM 15801 RGSM minnow

ANS

- Age 0: n = 3
- Age 1: n = 12
- Age 2: n = 5

Cowley et al.

Age 0: n = 0

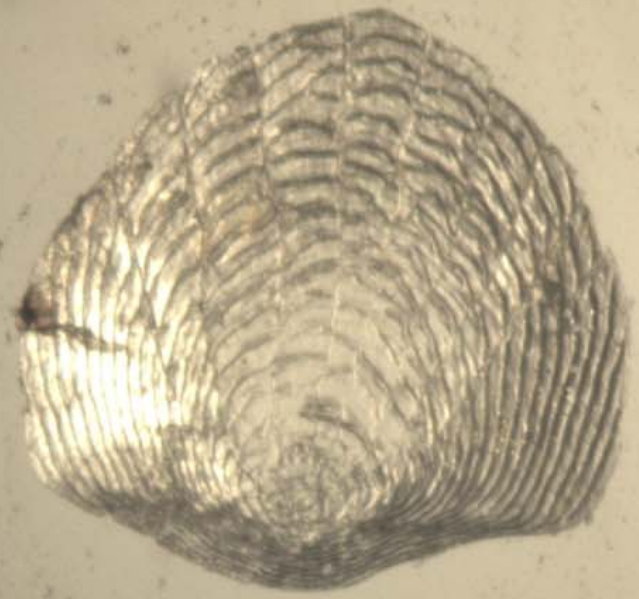
Age 1: n = 1

Age 2: n = 3

Age 3: n = 4

Age 4: n = 4

Age 5: n = 1

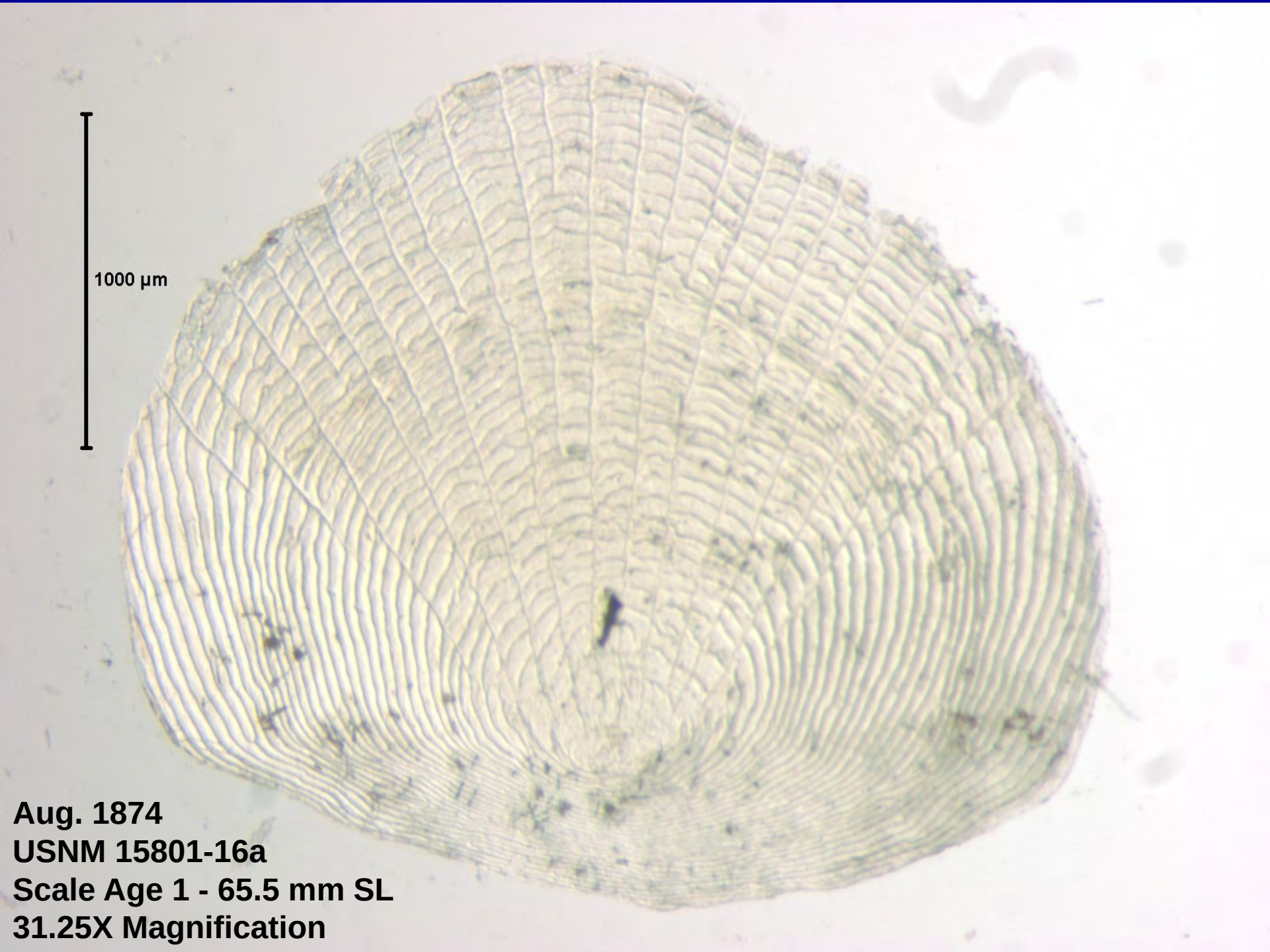


USNM 15801-20

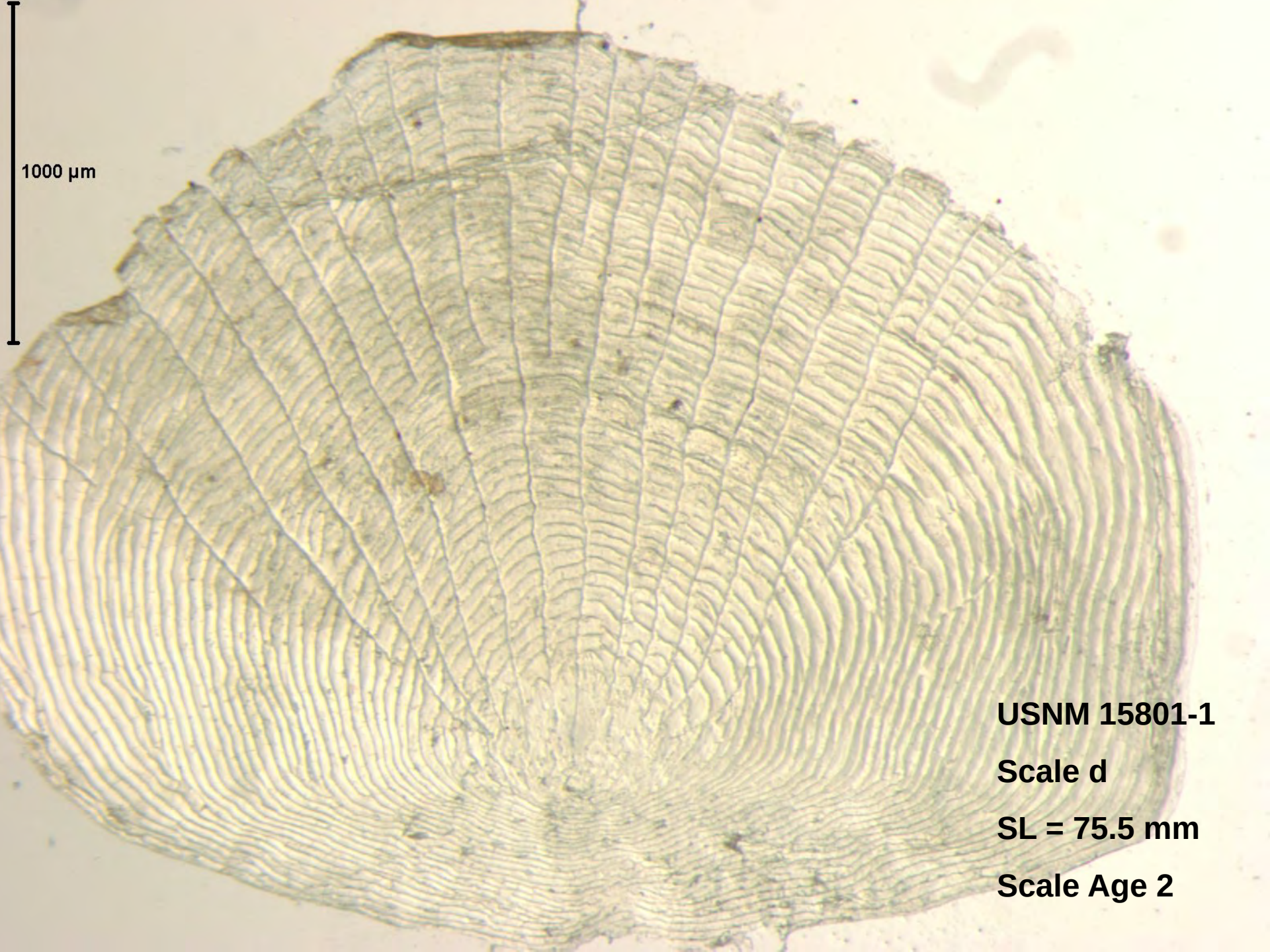
Slide b

34 mm

Age 0



Aug. 1874
USNM 15801-16a
Scale Age 1 - 65.5 mm SL
31.25X Magnification


1000 µm
USNM 15801-1
Scale d
SL = 75.5 mm
Scale Age 2

USNM 15801-1d

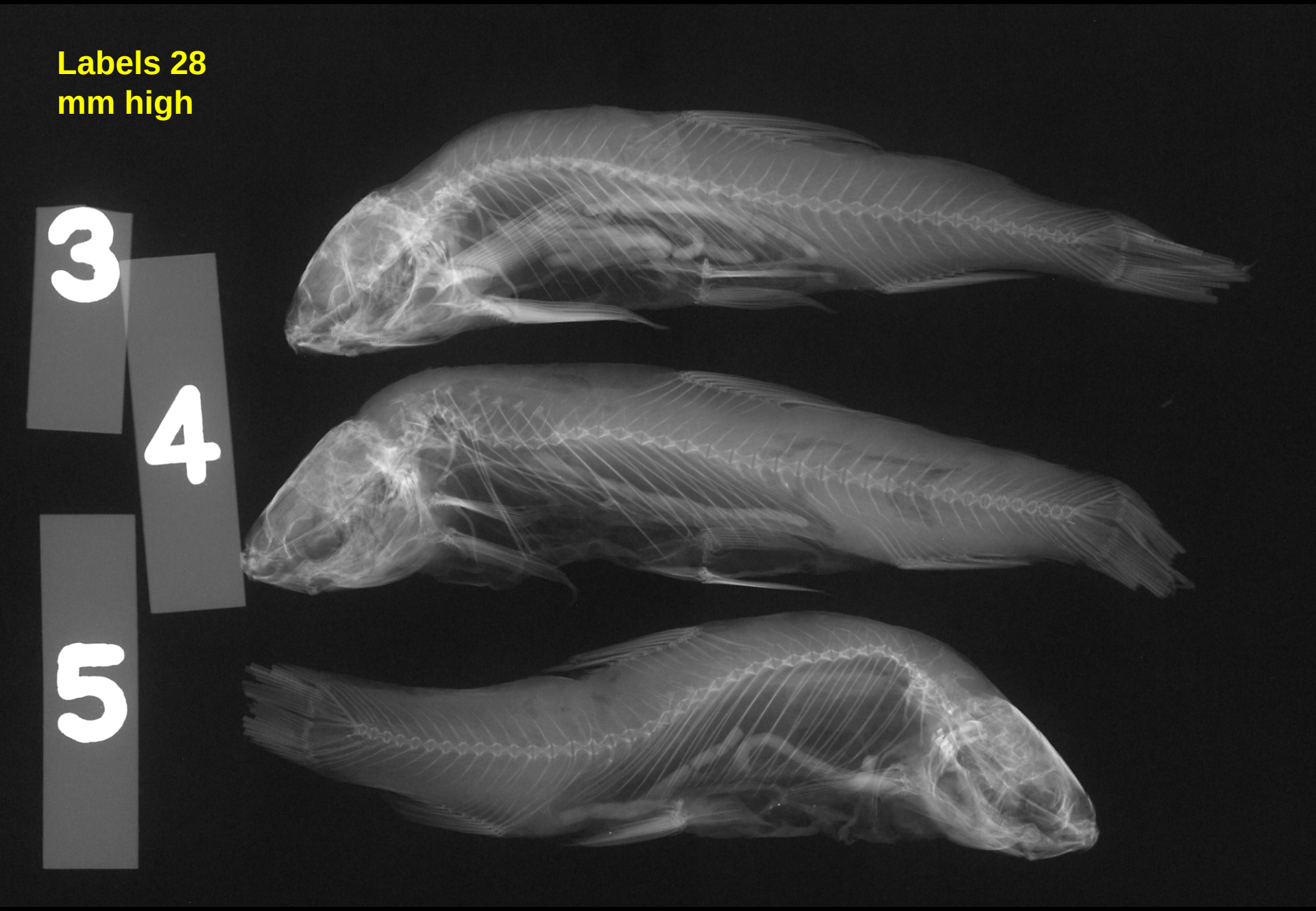
Recent Age 2

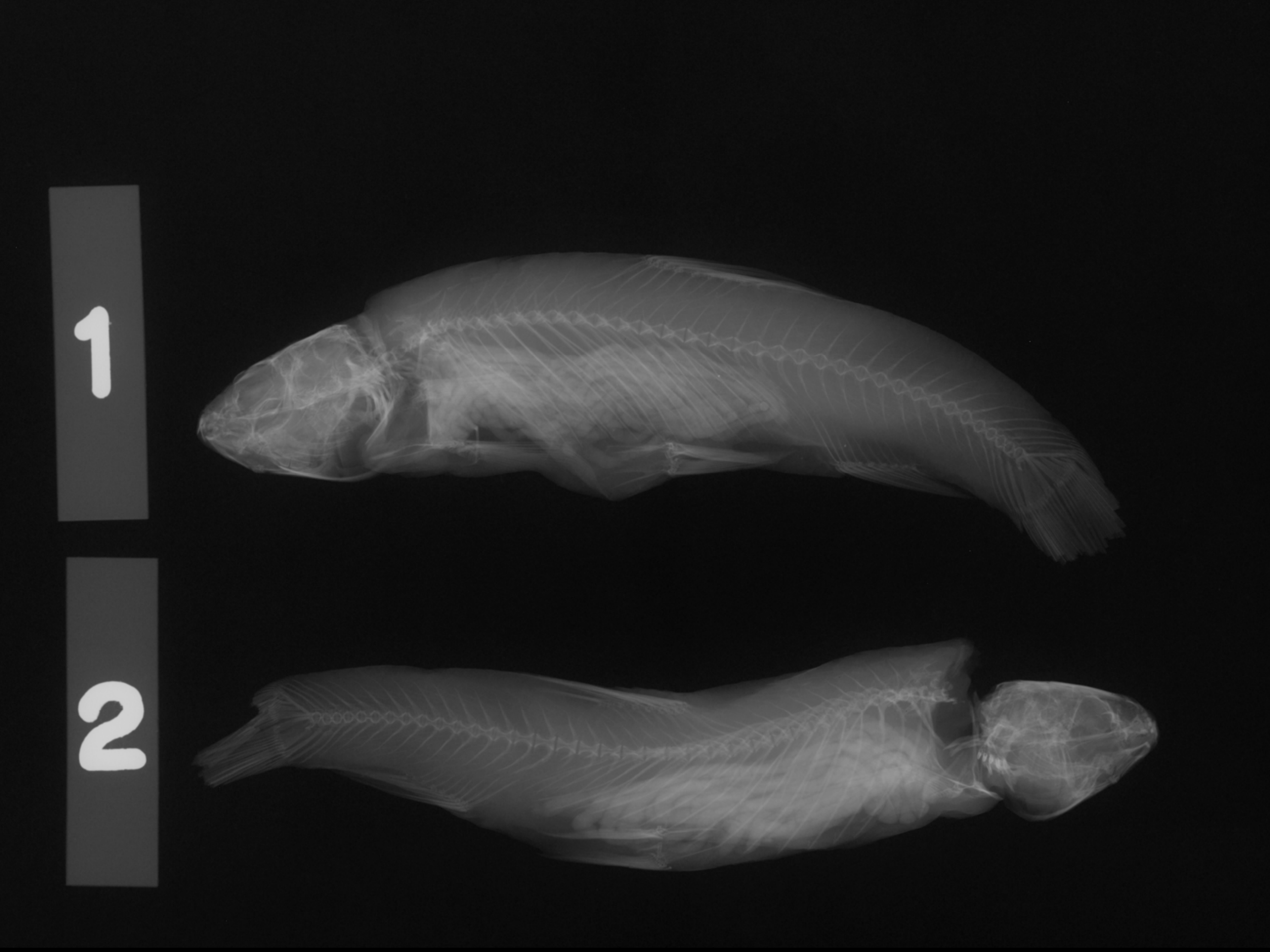
Conclusions

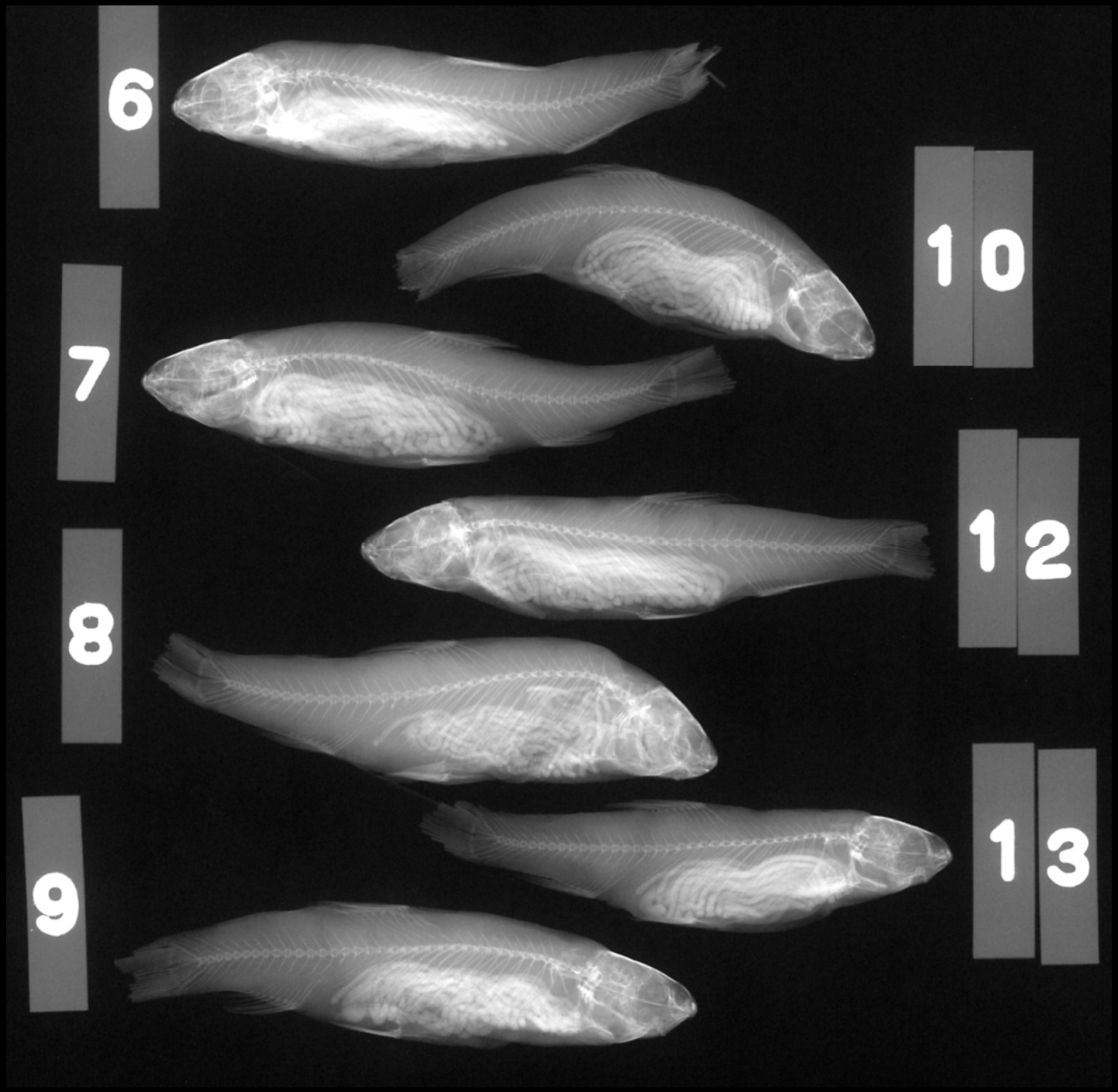
- Estimated hatch date of age-0 fish May 4-June 13, coincident with spring high flows
- Recent population consists of three age classes (0,1,2 or 1,2,3)
- Estimates from 2009-2010 fish
  - Fall: 0 (>89%), 1 (11%), 2 (<0.5%)
  - Spring: 1 (>91%), 2 (8%), 3 (0.2%)
- Historical sample shows three age classes (0, 1, and 2, similar to recent material)

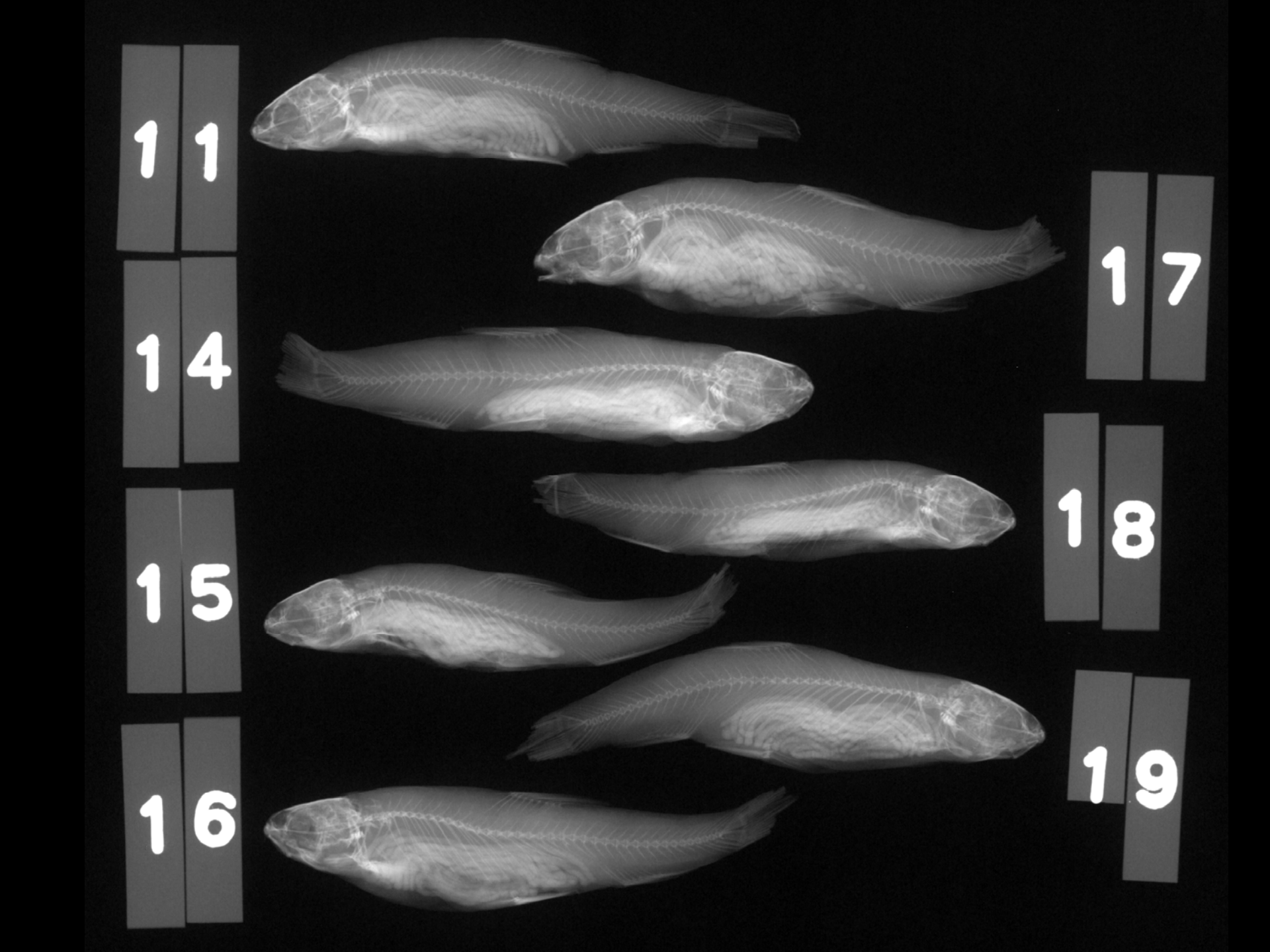
Questions?

From Abert, 1848

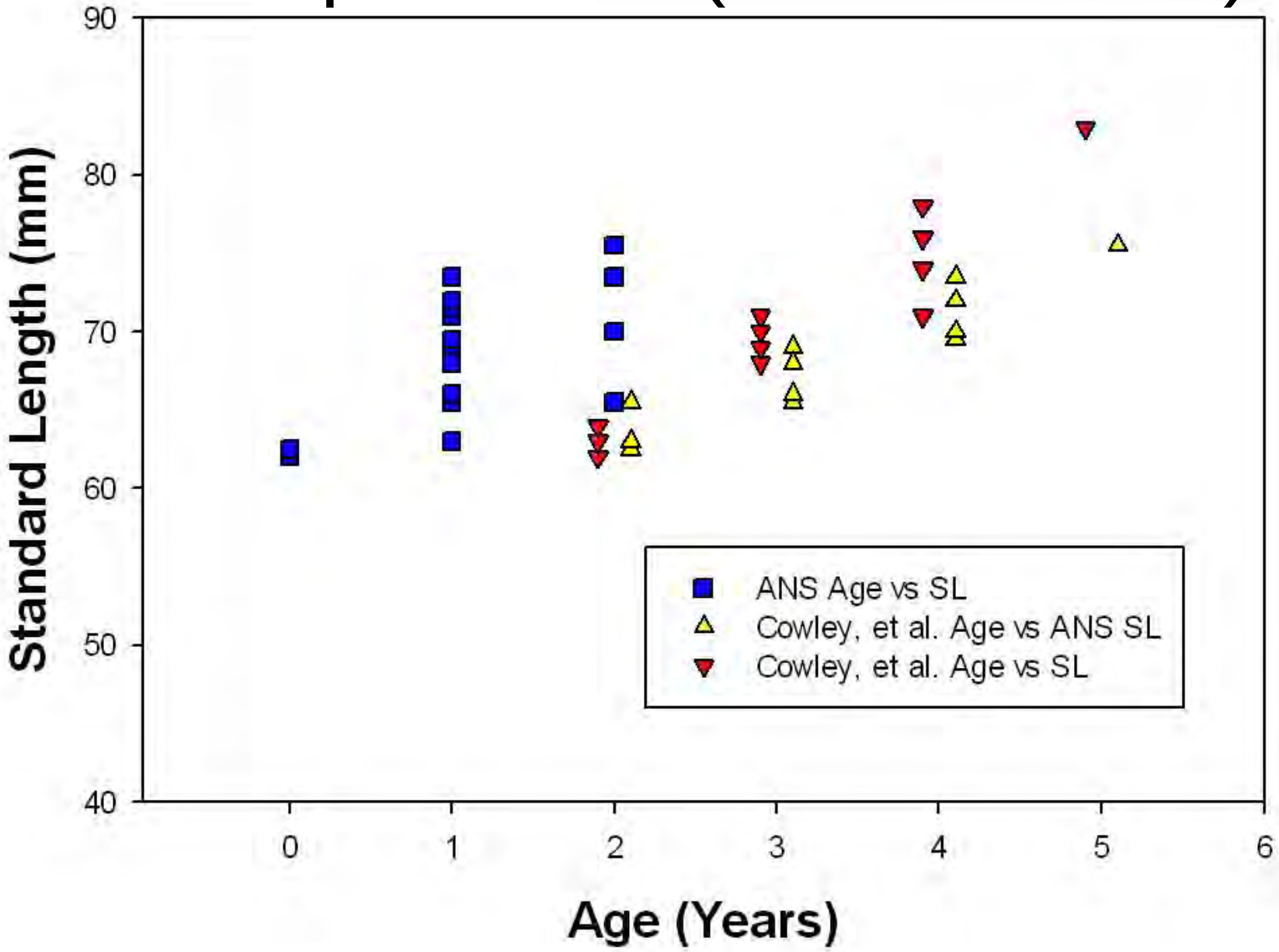

Labels 28
mm high
3
4
5


1
2


6
10
7
12
8
13
9

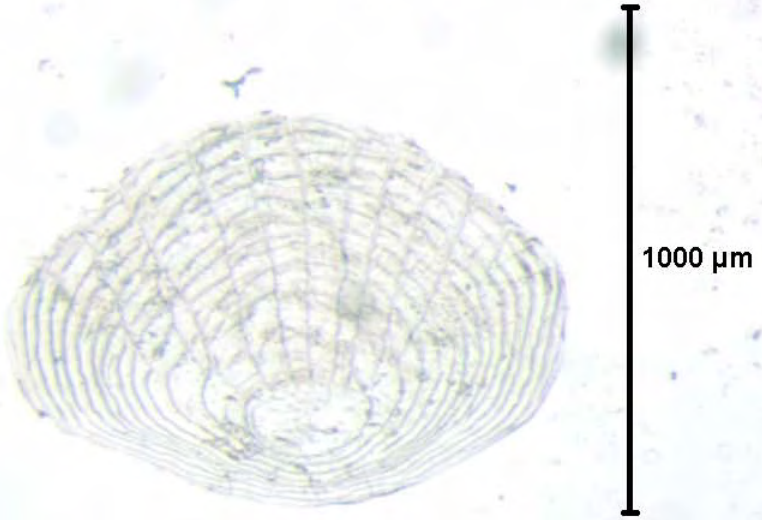

11
14
15
16
17
18
19

1874 Specimens (USNM 15801)

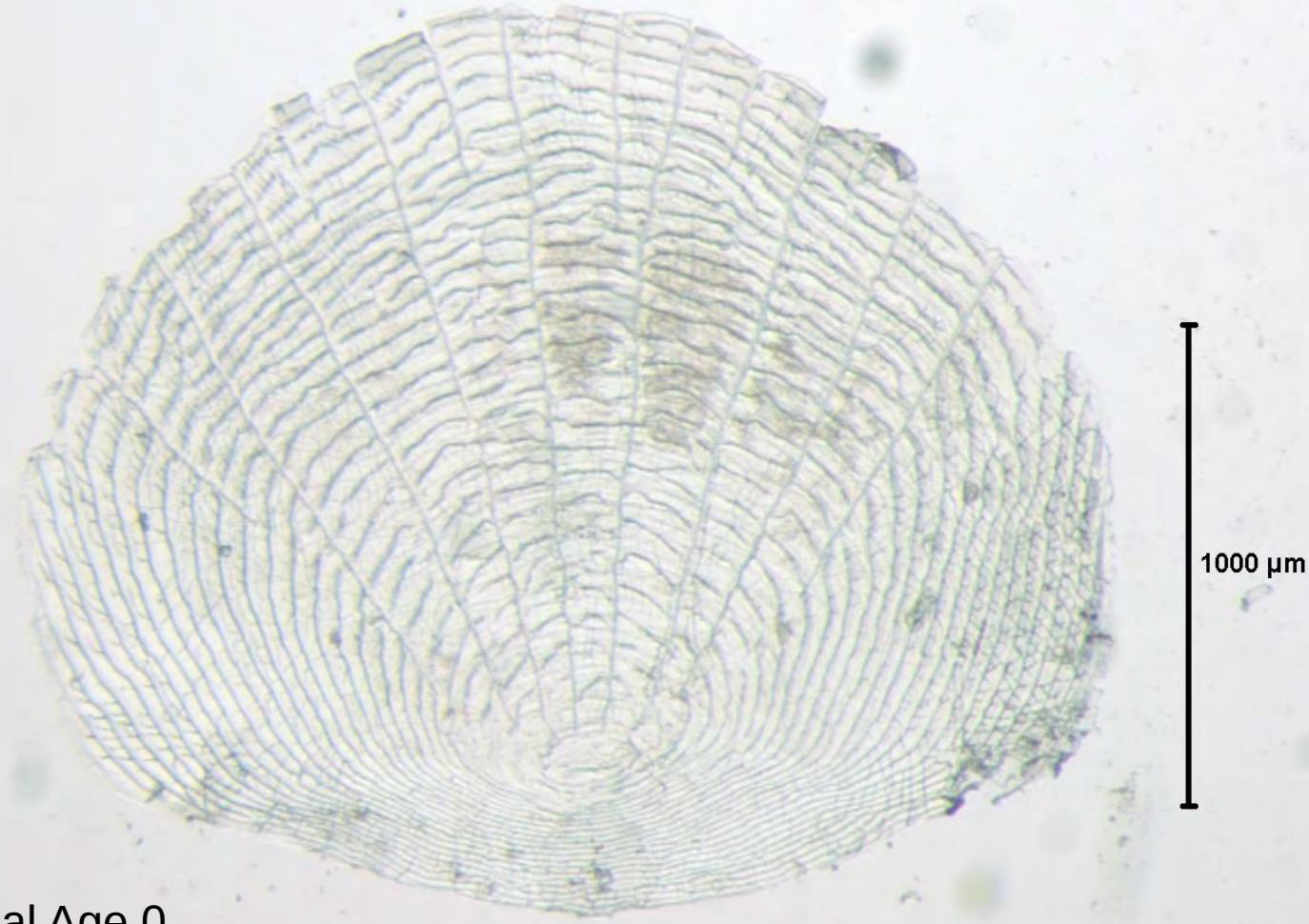


Series of Scales

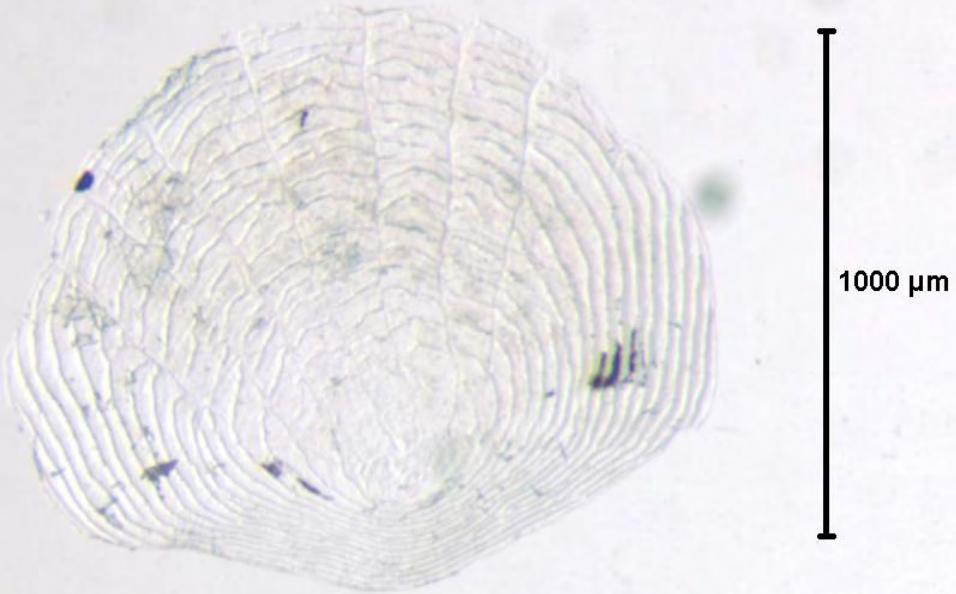
- Show best characteristics of annuli



73790 ISL-048
F4633b
Fall
Scale Age 0, Final Age 0
31.25X Magnification

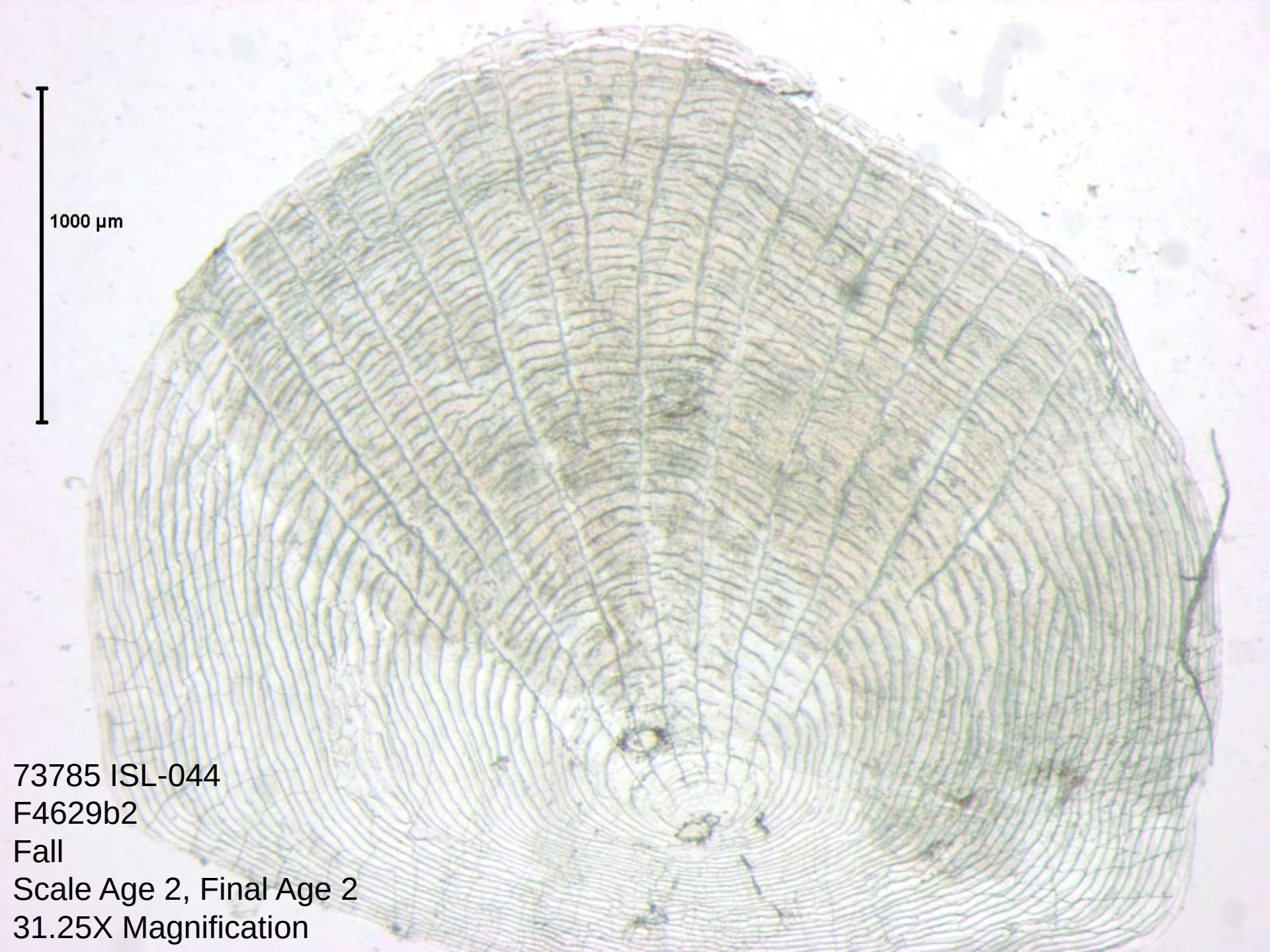


73766 ANG-015
F4560a
Fall
Scale Age 0, Final Age 0
31.25X Magnification

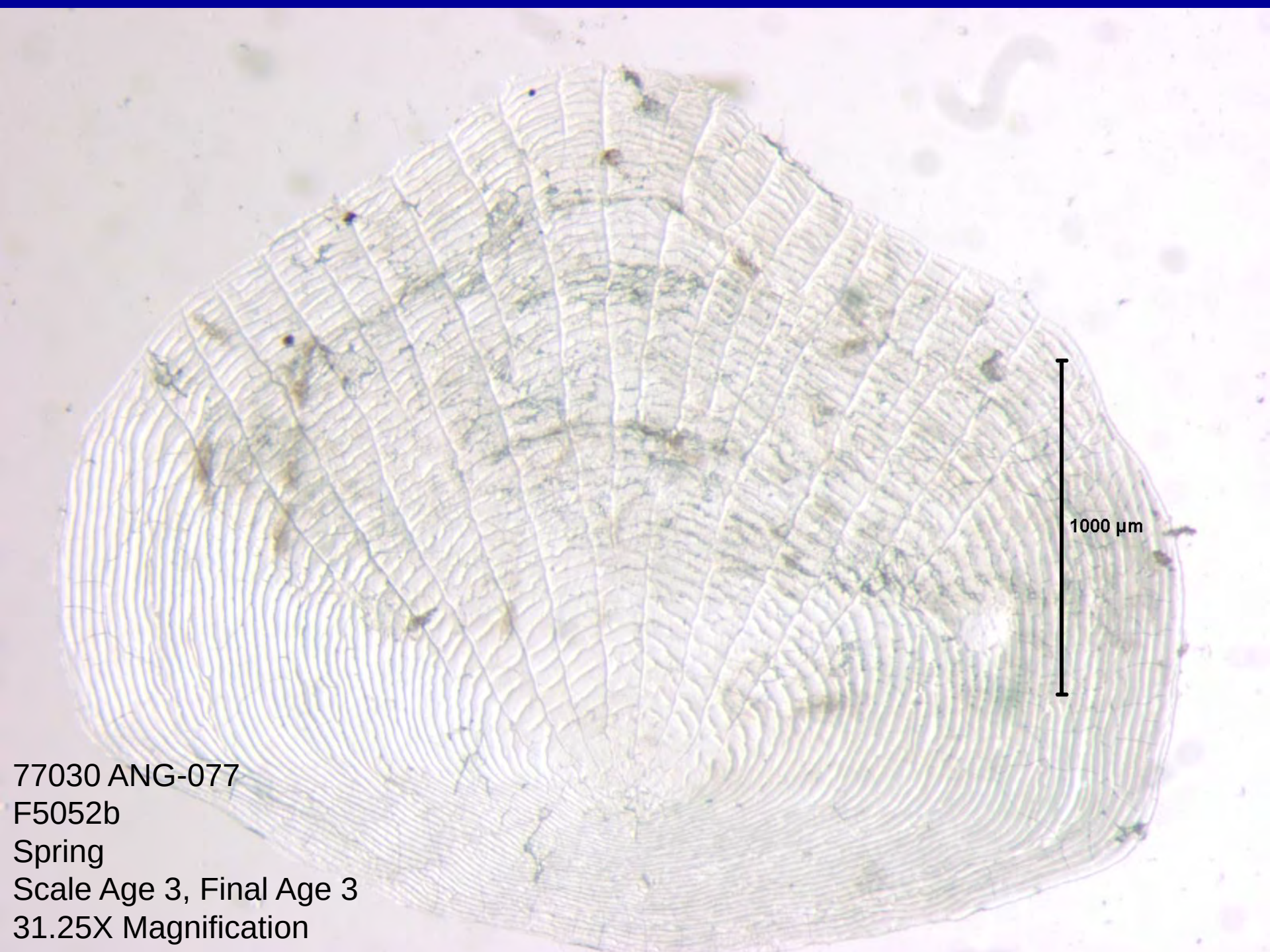


77021 ANG-052
F5031b
Spring
Scale Age 1, Final Age 1
31.25X Magnification

73772 ISL-022
F4607b
Fall
Scale Age 1, Final Age 1
31.25X Magnification



73785 ISL-044
F4629b2
Fall
Scale Age 2, Final Age 2
31.25X Magnification

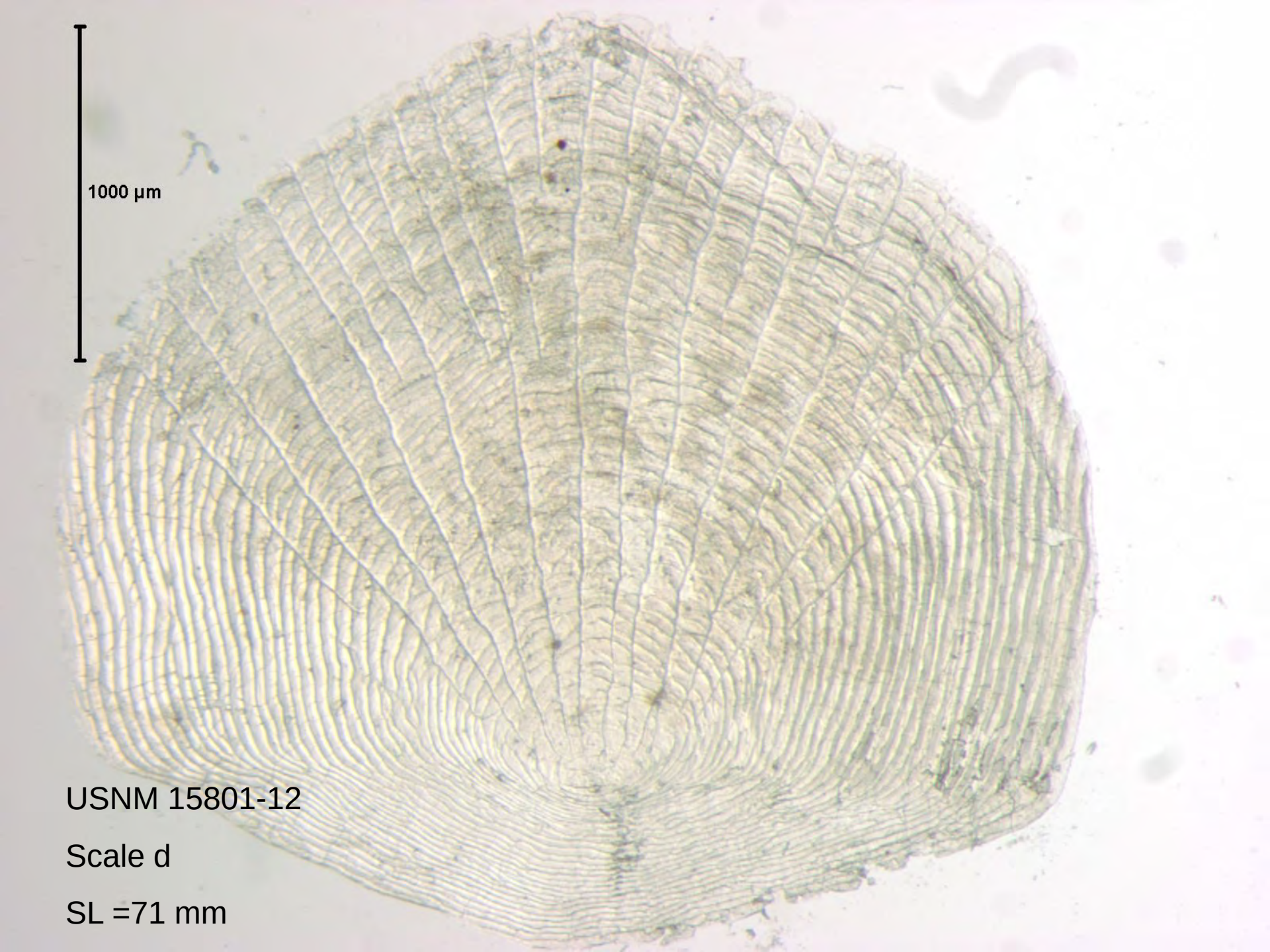


77030 ANG-077
F5052b
Spring
Scale Age 3, Final Age 3
31.25X Magnification

Additional USNM

15801-10
Scale a
SL= 66 mm

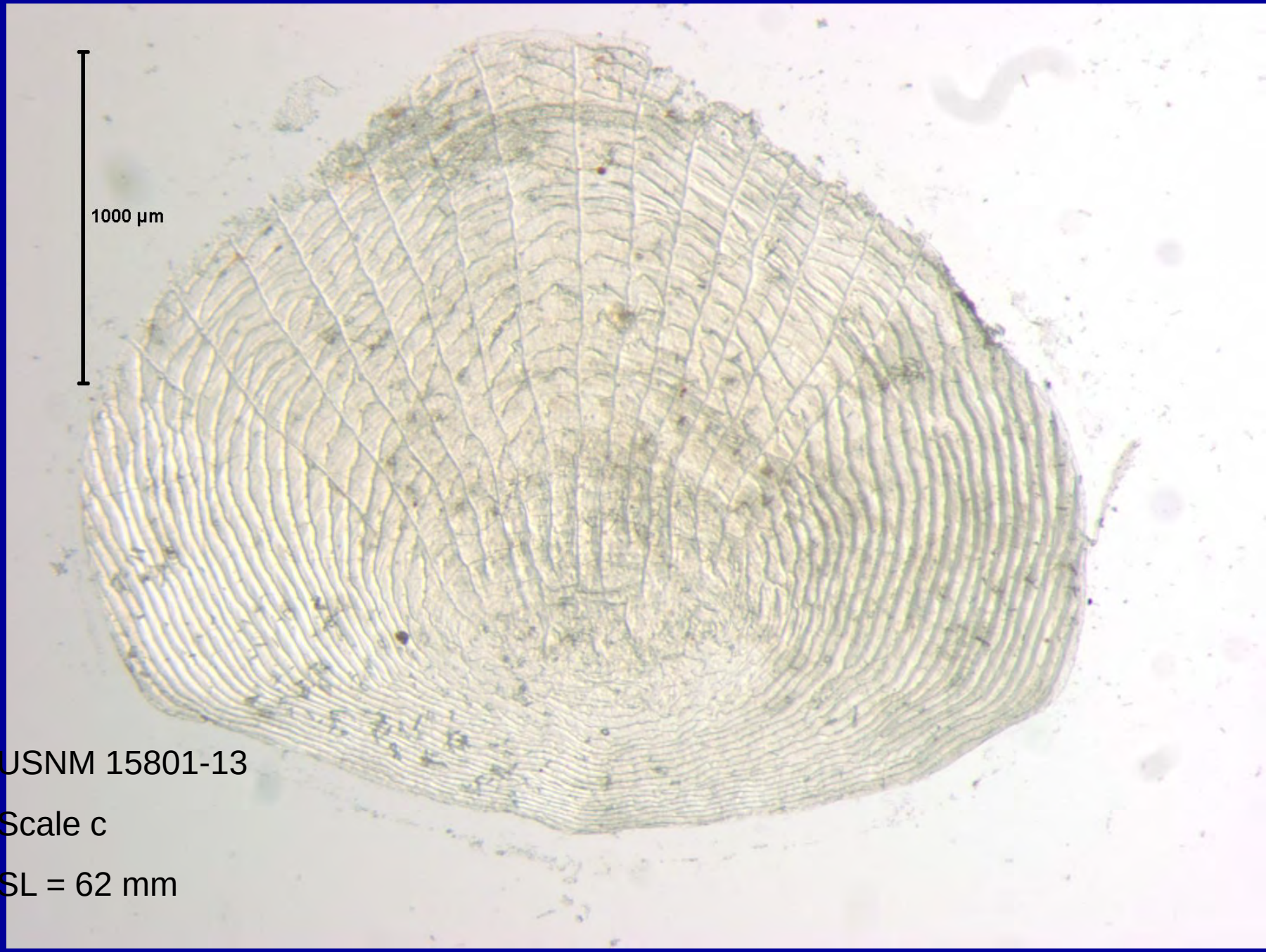
USNM 15801-11
Scale a
SL = 66 mm



USNM 15801-12

Scale d

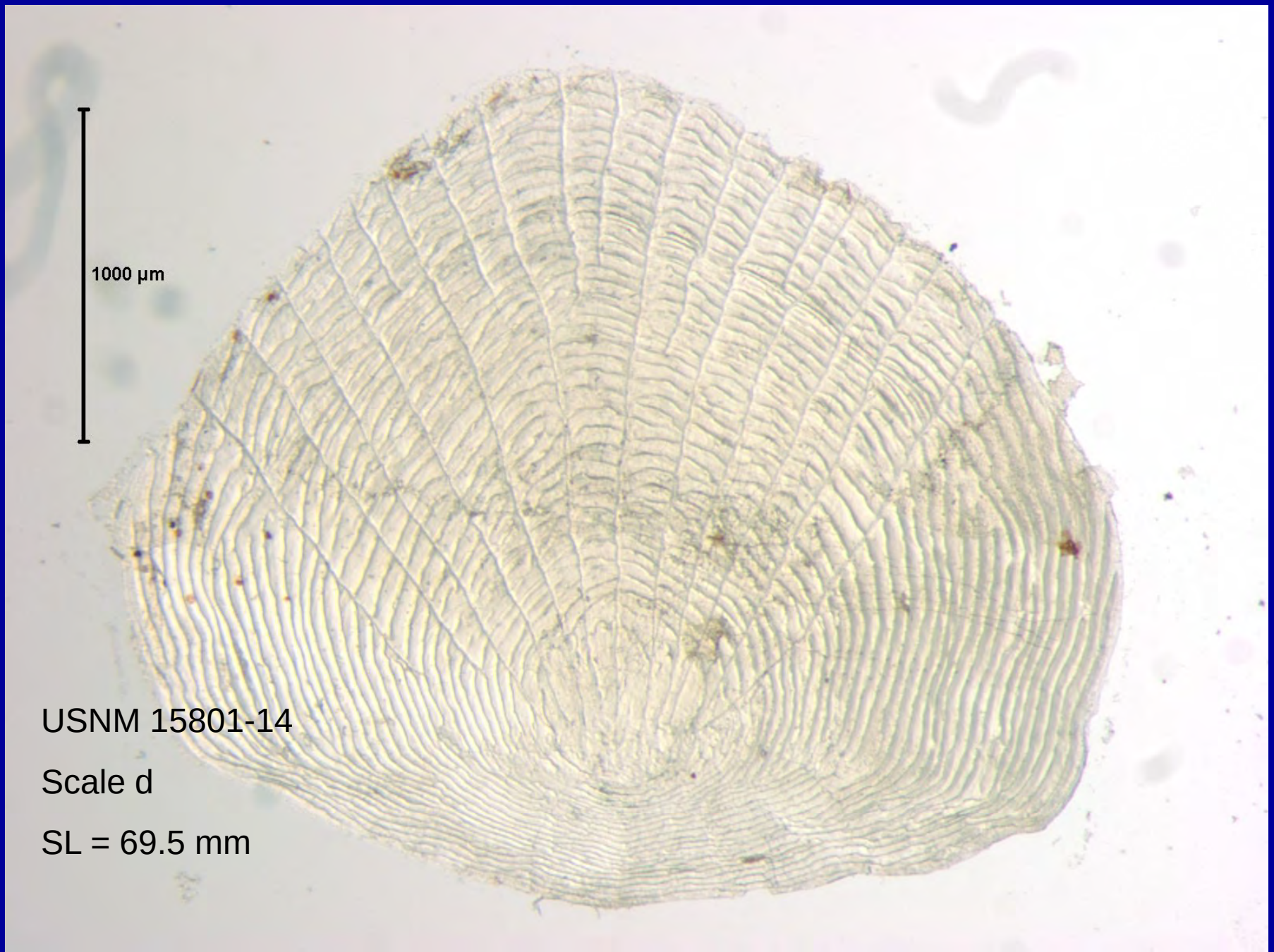
SL =71 mm



USNM 15801-13

Scale c

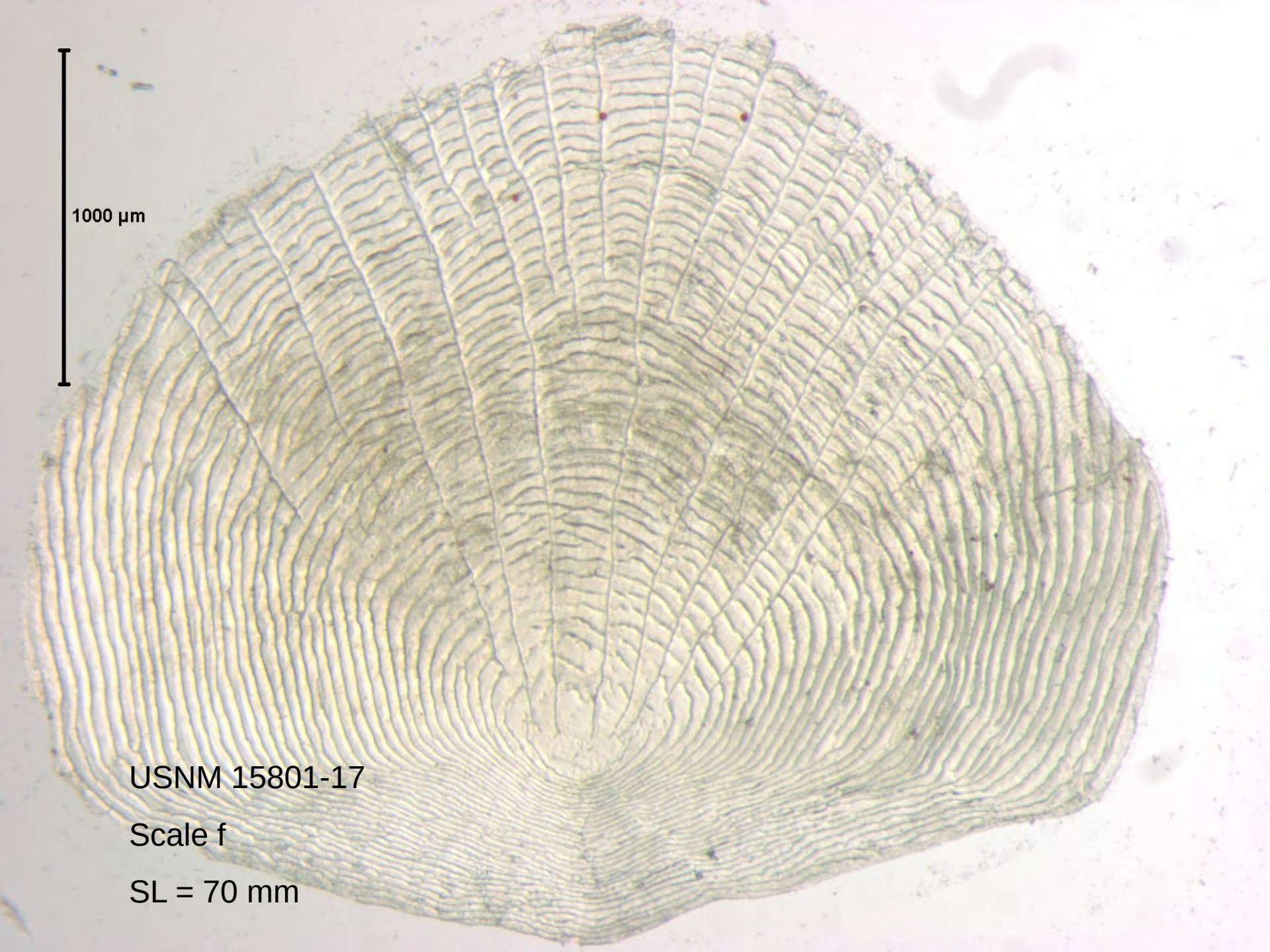
SL = 62 mm



USNM 15801-14

Scale d

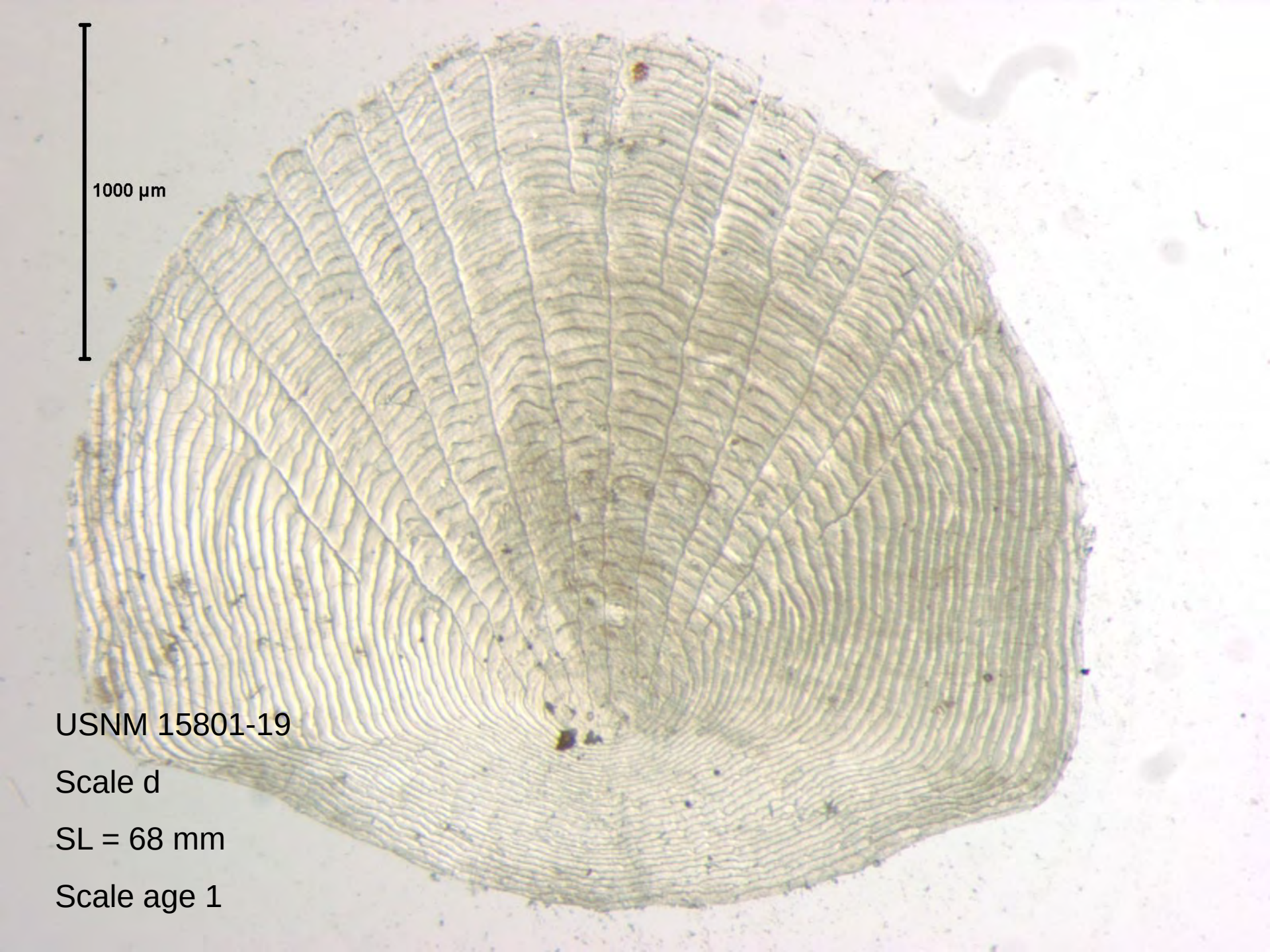
SL = 69.5 mm


1000 µm
USNM 15801-17
Scale f
SL = 70 mm

USNM 15801-18

Scale d

SL = 63 mm



USNM 15801-19

Scale d

SL = 68 mm

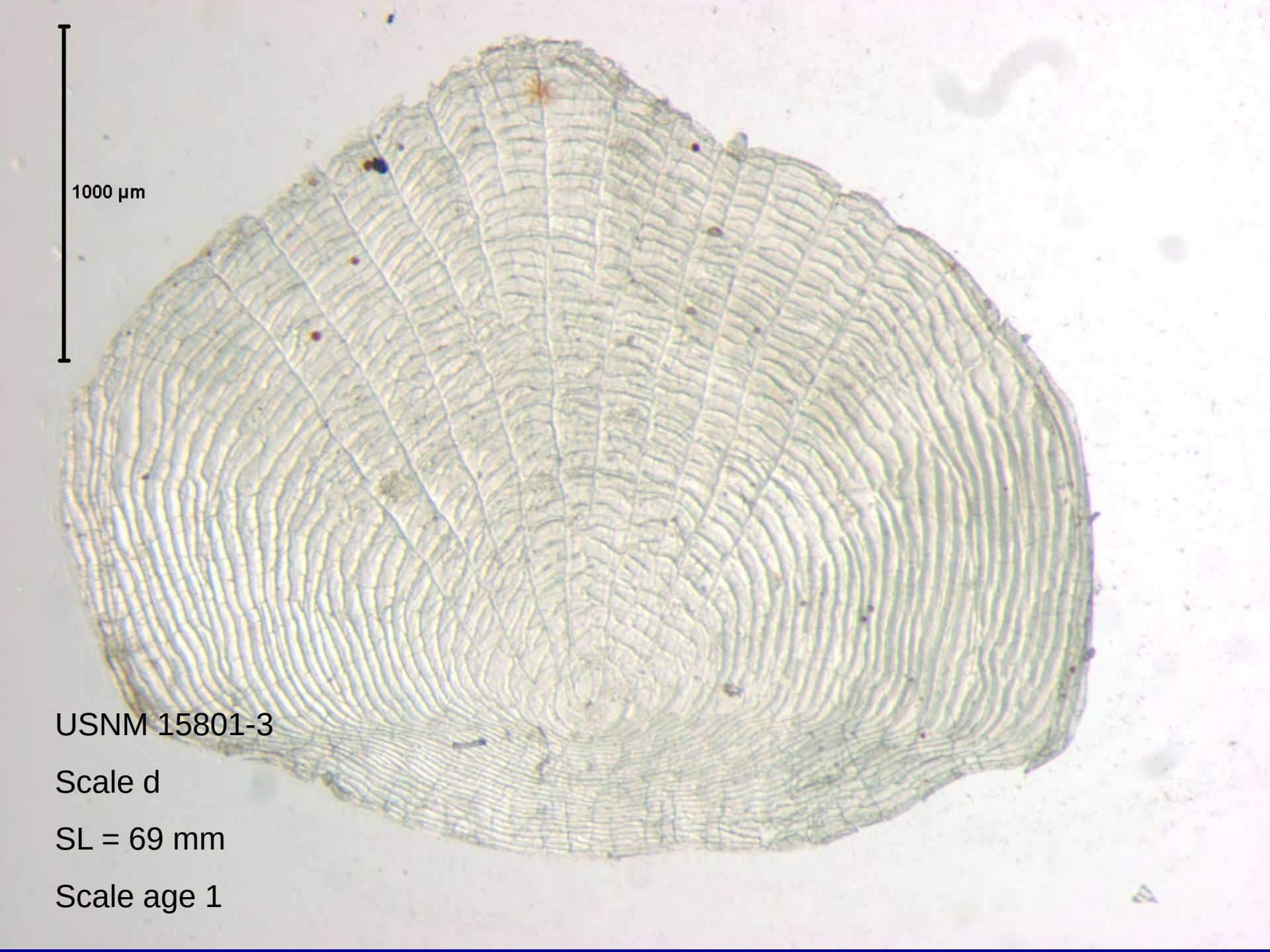
Scale age 1

USNM 15801-2

Scale a

SL = 73.5 mm

Scale age 2

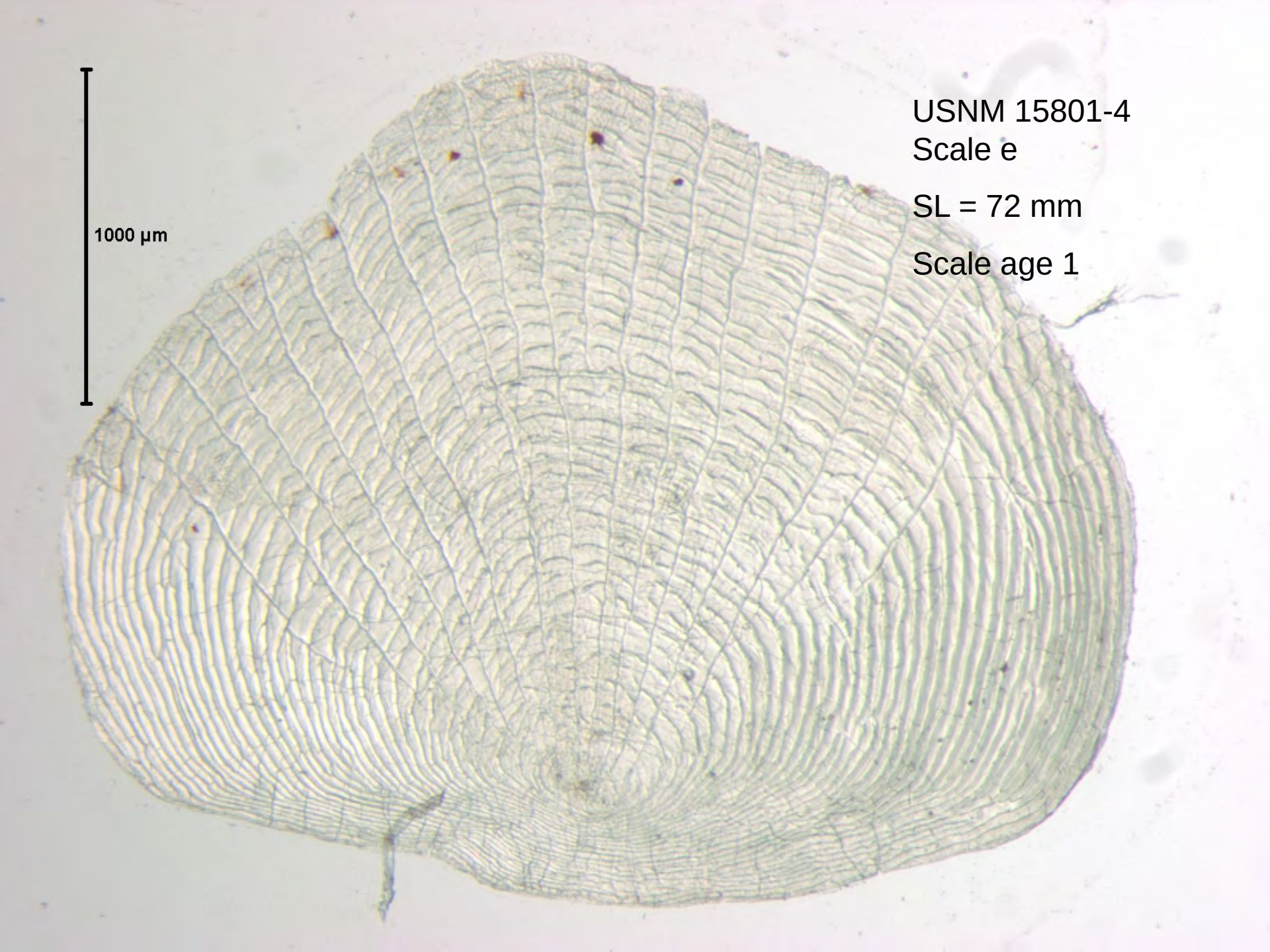


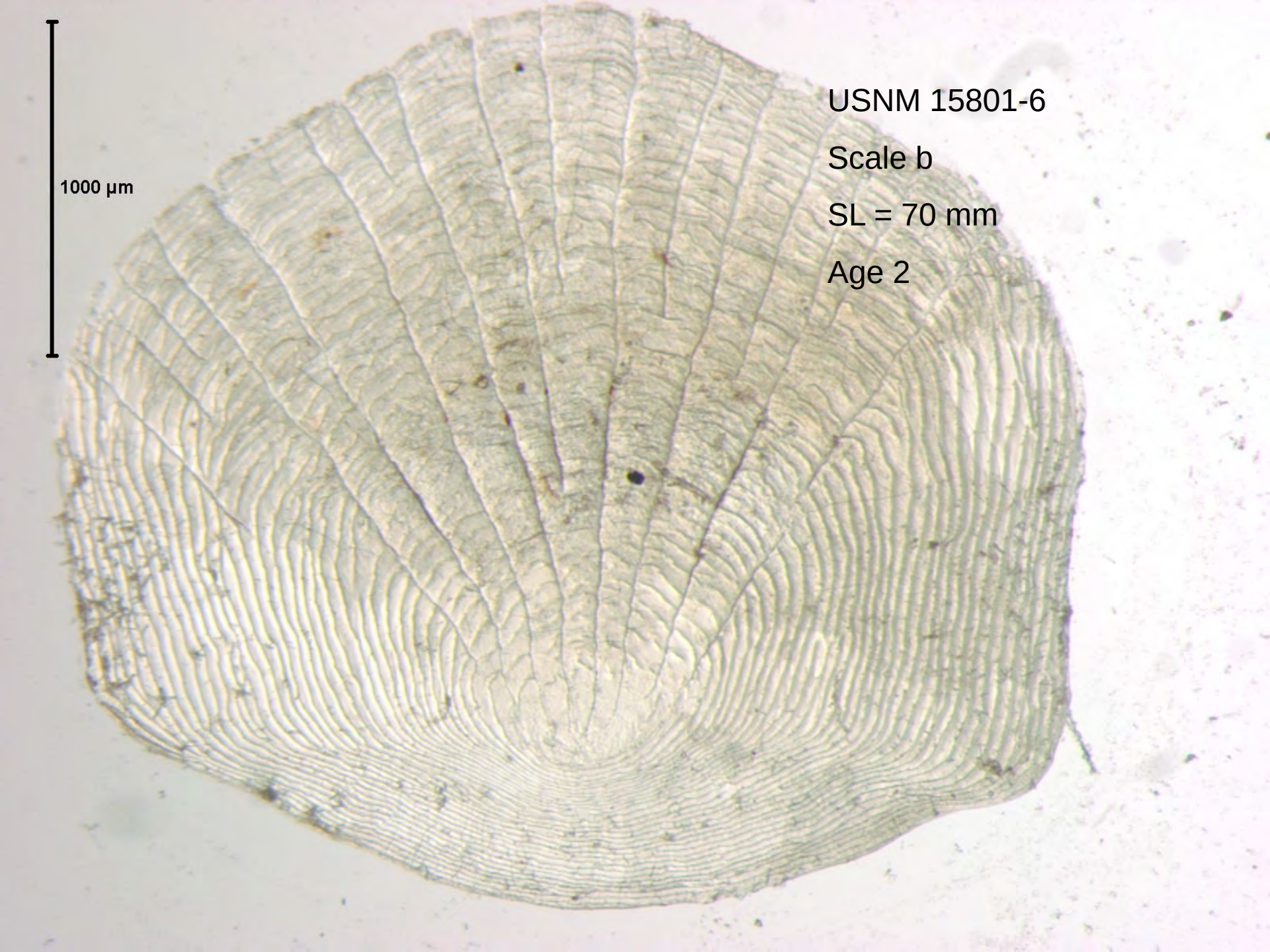
USNM 15801-3

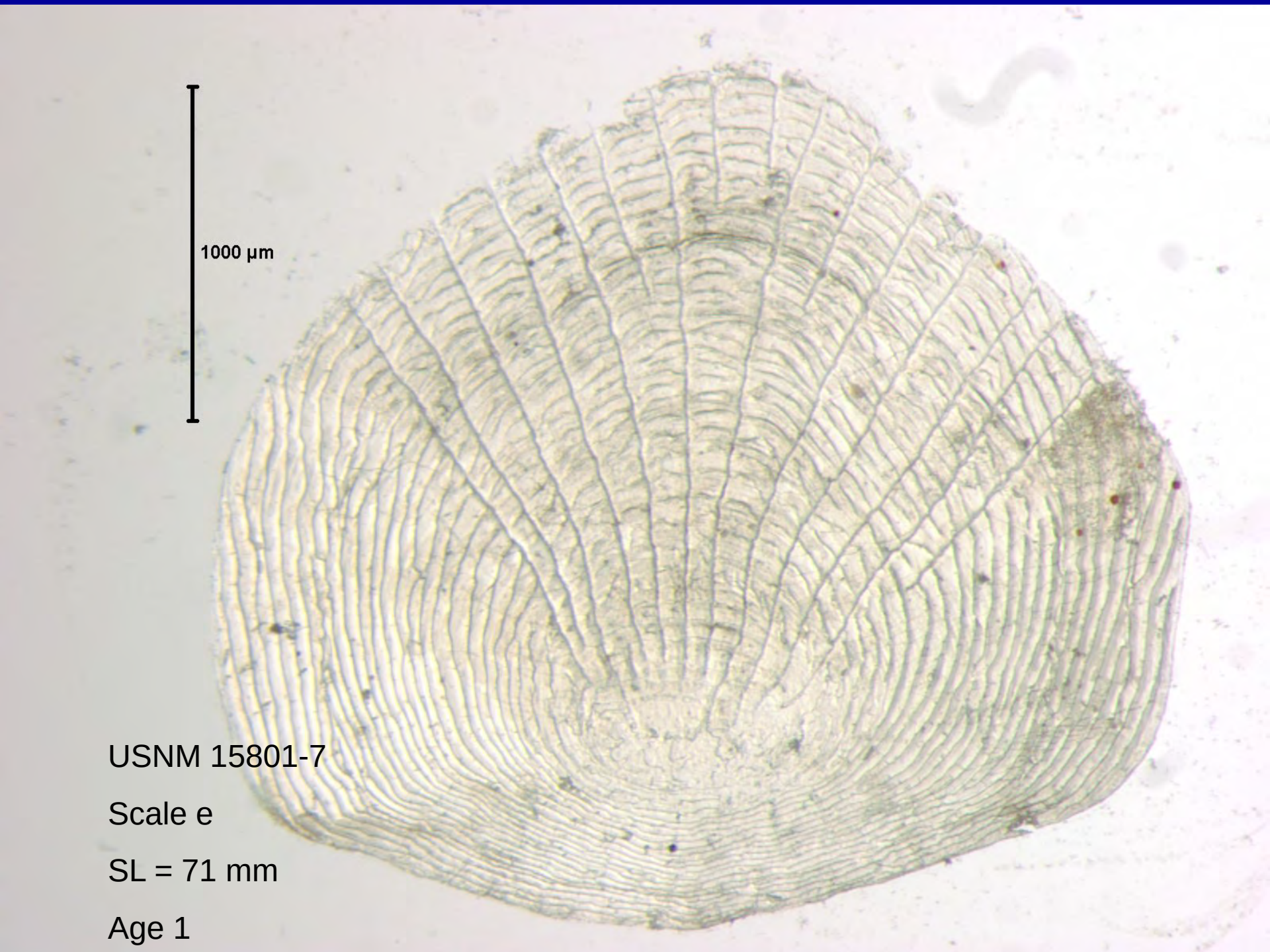
Scale d

SL = 69 mm

Scale age 1


1000 µm
USNM 15801-4
Scale e
SL = 72 mm
Scale age 1


1000 µm
USNM 15801-6
Scale b
SL = 70 mm
Age 2



USNM 15801-7

Scale e

SL = 71 mm

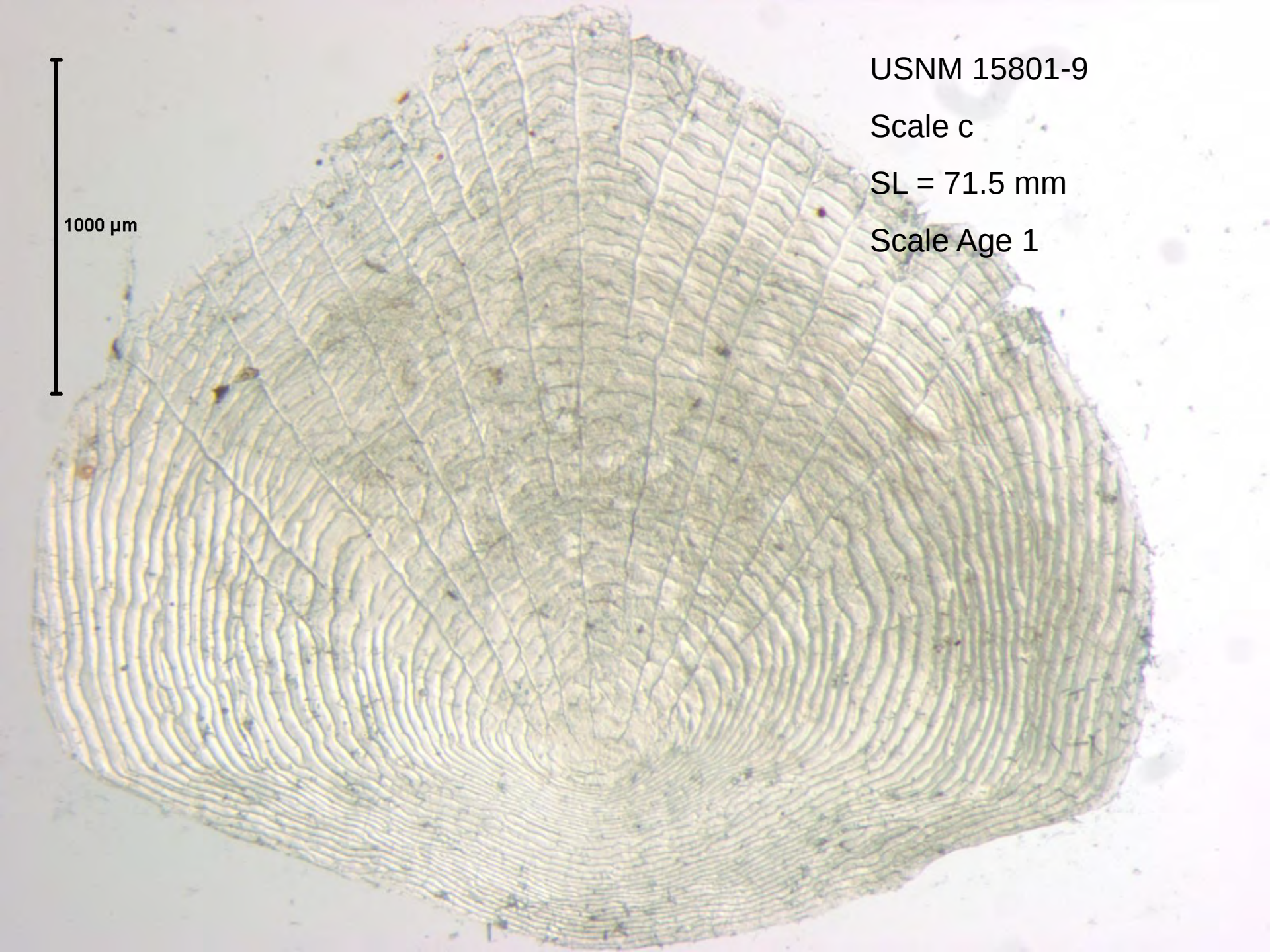
Age 1

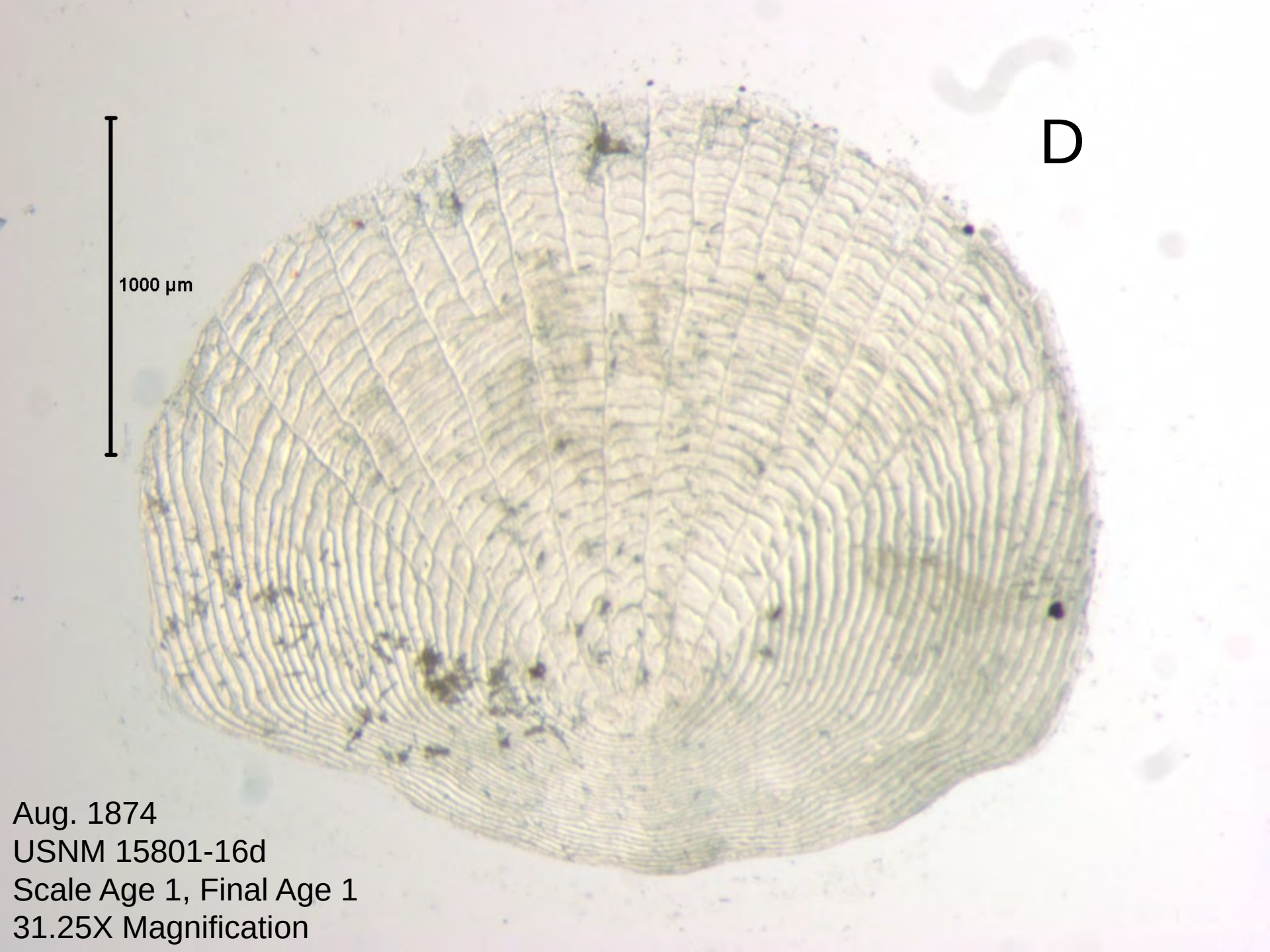
USNM 15801-8

Scale b

SL = 73.5

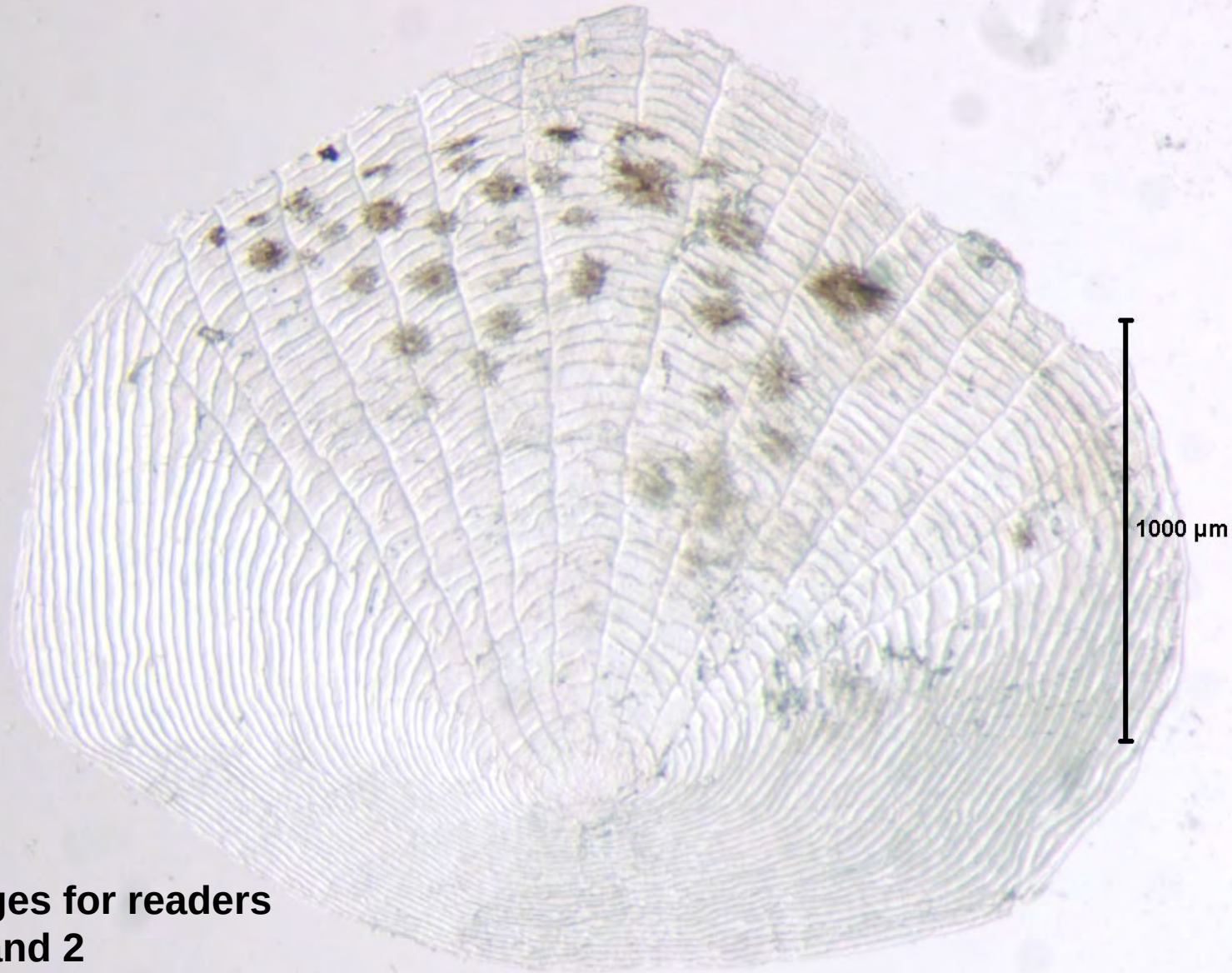
Scale age 1


1000 µm
USNM 15801-9
Scale c
SL = 71.5 mm
Scale Age 1



Aug. 1874
USNM 15801-16d
Scale Age 1, Final Age 1
31.25X Magnification

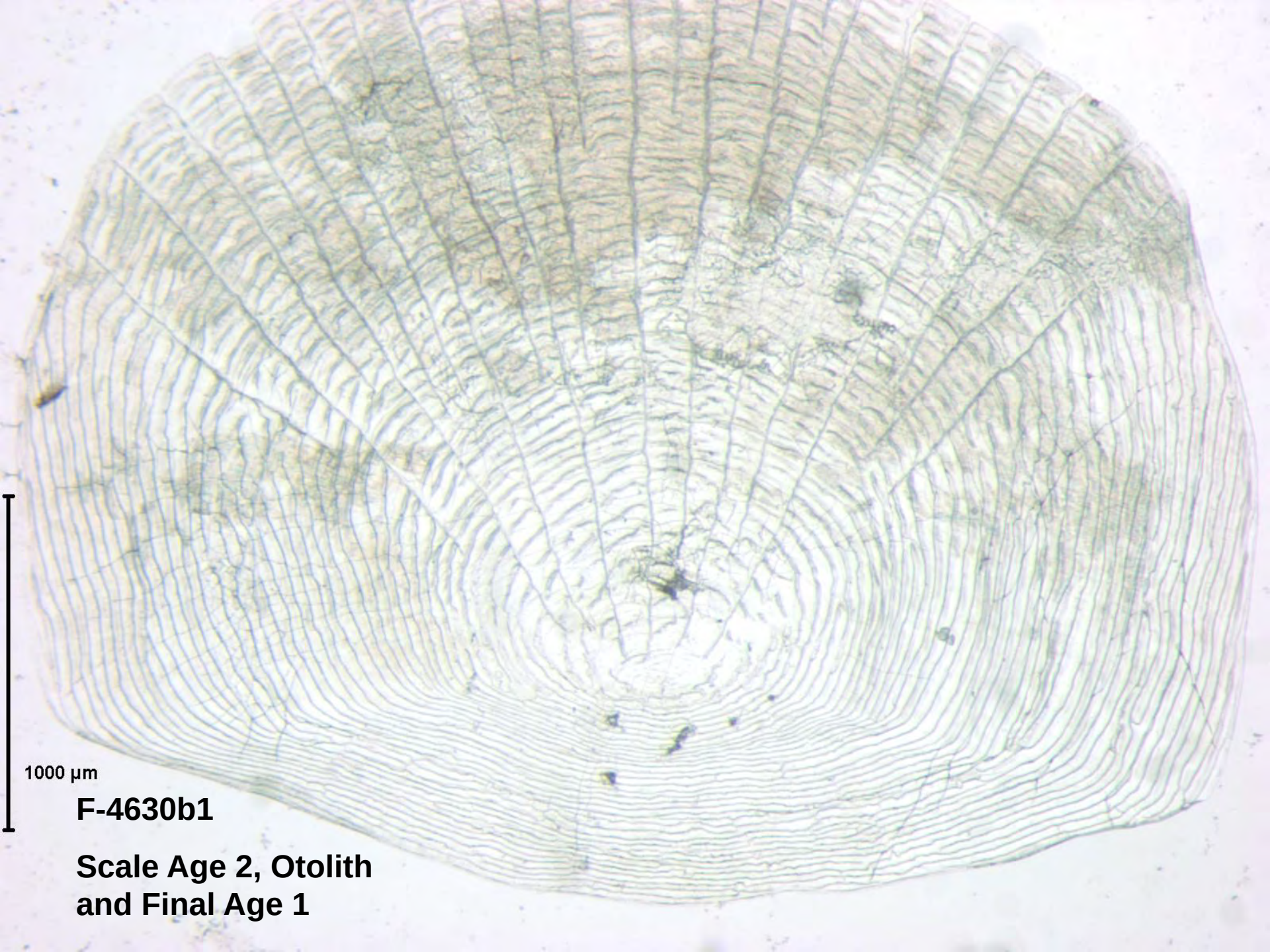
Examples of Scale Issues



F-5092b

Scale ages for readers were 1 and 2

Final age 2



F-4630b1

Scale Age 2, Otolith and Final Age 1