Atlantic States Marine Fisheries Commission

Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015.

Proceedings of the Tautog Ageing Workshop

May 2012

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Acknowledgements

The Atlantic States Marine Fisheries Commission thanks Old Dominion University's Center for Quantitative Fishery Ecology for preparing the tautog otoliths of the other participating states for the hard part exchange. The Commission also thanks ODU for welcoming workshop participants into their ageing lab for hands-on demonstrations and practice.

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ASMFC also appreciates the efforts of Commission staff Katie Drew and Chris Vonderweidt in coordinating the workshop and exchange and preparing this report.

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1 Introduction

The tautog (*Tautoga onitis*) is a member of the wrasse family found from Nova Scotia to South Carolina. Adults prefer hard-bottom habitats with either natural or man-made structure. Tautog show seasonal inshore-offshore migration patterns but do not appear to undertake extensive north-south migrations.

Tautog support primarily recreational fisheries in New England and the mid-Atlantic. The stock underwent a benchmark assessment in 2005 (ASMFC 2006), which was updated most recently in 2011 (ASMFC 2011). The update indicated tautog were overfished and overfishing was occurring. The assessment used an age-based model, the ADAPT VPA. The coastwide catch-at-age input was developed using regional age-length keys for the north (New York through Massachusetts) and south (North Carolina through New Jersey).

Tautog are aged using opercular bones, following the techniques of Cooper (1967) and Hoestetter and Munroe (1993). The dissected opercular bones are boiled in water for one to two minutes and cleaned of tissue. The bones are allowed to dry for two days and then read, usually with transmitted light, without magnification. Hoestetter and Monroe (1993) validated the annual nature of ring formation in opercula with marginal increment analysis.

Old Dominion University's Center for Quantitative Fishery Ecology, which ages Virginia's fishery-dependent samples, began using otoliths as a reference hard part to standardize their readings of tautog opercula in 2001. Whole otoliths are baked and embedded in epoxy. A low-speed saw is used to cut a thin section (0.4mm) through the core of the otolith. The section is mounted on a slide and read with a microscope. Processing otoliths requires more hands-on time and more sophisticated equipment and supplies than processing opercula.

This difference in technique raised concerns that the Virginia data were not comparable to the age data of the other states. As a result, the benchmark assessment and update did not include the most recent years (2001 – present) of age data from Virginia (ASMFC 2006).

At the request of the Tautog Management Board, the Commission organized a hard part exchange and ageing workshop for tautog. The objectives were to assess the precision of age readings between states and come to a consensus on best ageing practices for tautog to ensure consistency in age assignment going forward.

2 Hard Part Exchange Results

A total of nine labs from eight states participated in the hard part exchange. Each state provided 10 opercula and, if available, the corresponding otoliths from the same fish. States were asked to provide samples that covered the full range of sizes observed in their collections. Total length of sampled fish ranged from 142 mm to 777 mm, with the majority of samples in the 300 – 600 mm range (Figure 1). A total of 82 opercula and 72 otoliths were provided. ODU processed the whole otoliths that were provided by other states.

The samples were anonymized so that participants did not know the state of origin or which otolith matched which operculum. The samples were mailed to each lab in turn. When the labs completed their reads, they submitted them to Commission staff via e-mail and sent the samples to the next lab.

A total average CV was calculated for the operculum samples and for the otolith samples. In addition, the average CV was calculated for the operculum vs. otolith comparisons and the state vs. state comparisons. Bowker's test of symmetry (Evans and Hoenig, 1998) was used to test for systematic bias in the state vs. state and hard part comparisons. Maryland did not submit otolith ages; only operculum age results are presented for that state.

2.1 Operculum vs. Otolith Ages

Only ODU currently reads tautog otoliths. Readers from other states had little to no experience or training reading tautog otoliths. Despite this, the level of precision was similar for both operculum and otoliths. The average CV for the operculum samples was 13.2% across all states. The average CV for the otolith samples was 13.6% across all states.

States' operculum-otolith comparisons showed a range of CVs, from a low of 8% to a high of 18% (Tables and Figures
Table 1, Figures 2-9). None of the states exhibited significant bias, as indicated by Bowker's test of symmetry, indicating that the ages assigned by opercula were not systematically different from ages assigned by otoliths. It should be noted that the sample size of older fish was small, which limits the power of the test to detect a systematic difference at older ages.

2.2 State Comparisons

Between-state comparisons resulted in a range of CVs, from lows of 4.6% (operculum ages) and 3.5% (otolith ages) to highs of 18.3% (operculum ages) and 17.5% (otolith ages) (Tables 2 and 3, Figures 9 – 43). Some states showed significant systematic differences (Bowker's test, $p<0.05$). Massachusetts aged opercula younger than all other labs. ODU aged opercula younger than Maryland at all ages, and aged opercula younger than Rhode Island at younger ages and older than Rhode Island at older ages. New York aged opercula older than New Jersey.

Overall, the CVs of readings between ODU and other states were similar to CVs of other state comparisons, and ODU's readings did not exhibit significant systematic differences from most other states.

The first annulus in tautog opercula can become obscured by additional bone growth in older, larger fish and occasionally must be inferred based on the radius of the first visible annulus. It was suggested that if southern fish grow faster and have a wider first annulus than northern fish, states might show more agreement in readings of fish from their region than fish from the other region. Bias plots and CVs were calculated for operculum ages of northern fish and southern fish (Table 4, Figures 44 – 71). Although some state-state comparisons had lower CVs for one region, there were not large differences between the pooled CVs and the region-specific CVs. In addition, there did not appear to be a geographic pattern in the CVs of state comparisons; that is, CVs were not higher between more distant states.

3 Workshop Recommendations

3.1 Virginia's operculum ages are acceptable for use in the next benchmark assessment.

The CVs in the ODU-state comparisons were similar to the CVs of other state comparisons. There was evidence of systematic differences between ODU and MA, MD, and RI; however, comparisons of other states also showed systematic differences. Thus, workshop participants concluded that Virginia's age data were not different enough from the other states to warrant exclusion, despite the fact that they use a slightly different technique to age tautog opercula.

3.2 Operculum collection should remain the standard for biological sampling of the tautog catch, but paired sub-samples of otoliths should be added.

The exchange did not reveal significant systematic differences between ages assigned by opercula and ages assigned by otoliths. Given the relative ease of processing opercula, the long time-series of operculum ages, and the age of the plus group (12+) used in the stock assessment, there is no immediate need to switch to otoliths as the preferred ageing structure.

Even without training in reading tautog otoliths, the level of precision for otoliths and opercula was similar. This suggests that with more experience, states could get improved precision by using otoliths to age tautog or to provide a reference for difficult-to-read opercula. Workshop participants recommend that states begin collecting paired sub-samples of tautog opercula and otoliths from 50 fish per year evenly spread across the observed size range. This paired collection can serve as a reference tool to help standardize readings and improve precision of age assignments. States that do not have the resources to process and read the otoliths can archive the samples for future work.

3.3 States should calibrate their age readings every year by re-reading a subset of samples from previous years before ageing new samples. States that do not currently assess the precision of their age readings over time should do so by re-ageing a subset of their historical samples.

The results of the hard part exchange provide a snapshot of current rates of precision and bias between states. However, the exchange cannot determine whether that precision or bias has changed over time. Labs should assess the repeatability of their age readings over time by re-ageing a subset of their samples from earlier years. Ideally this should be done before reading the current year's samples as a training exercise to maintain consistency in technique over time.

States that have not consistently assessed their precision over time should re-age a subset of historical samples to help determine whether the results of the exchange are valid for earlier years. Commission staff will coordinate with the states to collect and disseminate the results of this exercise in the winter of 2012/2013. These data will allow the Tautog Technical Committee to evaluate whether there has been consistent bias between states over time and, if so, how best to incorporate historical data into age-length keys for the next benchmark assessment.

In addition to rereading historical samples, Massachusetts is also rereading the exchange samples to determine the cause of the systematic differences between Massachusetts and the other states.

3.4 Regional reference collections of paired operculum and otolith samples should be assembled and regular exchanges should be scheduled to maintain and improve the precision of age readings between states that will be pooled in the regional age-length keys.

Although there is interest in assessing tautog on a regional or even state-specific basis, biological samples will still need to be pooled at some level, and maintaining consistency and precision between labs is important.

States can maintain their own collections of paired otolith and operculum samples, and Commission staff can facilitate annual or biennial exchanges of hard parts.

4 Literature Cited

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ASMFC 2011. Tautog Assessment Update Summary. 9 pp.

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Evans, G.T. and J.M. Hoenig. 1998. Testing and viewing symmetry in contingency tables, with application to readers of fish ages. Biometrics 54 (2): 620-629.

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5 Tables and Figures

Table 1: Precision and bias of otolith-operculum comparisons for each state

		% Agreement		
	Average CV	Absolute	Within 1 year	Bowker's p
ODU	8.1%	45.8%	91.7%	0.32
VIMS	13.1%	34.7%	79.2%	0.40
DE	16.0%	25.0%	68.1%	0.26
NJ	18.0%	23.6%	65.2%	0.31
NY	12.3%	34.7%	68.1%	0.31
CT	7.9%	51.4%	87.5%	0.42
RI	10.8%	35.3%	82.4%	0.69
MA	13.6%	25.0%	83.3%	0.15

Table 2: Average CVs of state vs. state operculum readings.

	ODU	**VIMS**	**MD**	**DE**	**NJ**	**NY**	**CT**	**RI**
ODU								
VIMS	***11.6***							
MD	***8.9***	***13.7***						
DE	9.8	***13.3***	6.7					
NJ	9.5	11.3	9.8	9.6				
NY	13.3	***18.4***	9.3	9.5	***11.3***			
CT	8	***13.6***	4.6	6.6	8.9	9.7		
RI	***10.3***	***11.1***	7.2	6.9	7.2	11	7.5	
MA	***7.5***	8.1	***14.3***	***13.6***	***10.6***	***18.3***	***13.2***	***12.1***

****Red font indicates significant deviation from symmetry (Bowker's p < 0.05)***

Table 3: Average CVs of state vs. state otolith readings.

	ODU	**VIMS**	**DE**	**NJ**	**NY**	**CT**	**RI**
ODU							
VIMS	9.5						
MD							
DE	13.2	14.9					
NJ	14.4	10.2	***17.5***				
NY	3.5	***10.1***	12.2	12.9			
CT	3.7	***11***	14	***14.6***	4.5		
RI	9.7	***12.4***	9.3	***15***	8.8	9.1	
MA	7.2	7.7	***12.7***	10.4	6.9	***9.3***	***10***

****Red font indicates significant deviation from symmetry (Bowker's p < 0.05)***

Table 4: Average CV of state vs. state operculum readings by region of sample origin (Northern fish/southern fish).

	ODU	VIMS	MD	DE	NJ	NY	CT	RI
ODU								
VIMS	12.6/10.5							
MD	7.5 /***10.2***	13.0/14.5						
DE	8.2/11.4	13.6/13.0	6.1/7.5					
NJ	7.9/11.2	8.5/14.3	9.4/10.2	9.0/10.3				
NY	13.1/13.6	18.8/18.0	9.7/8.9	10/8.9	12.7/9.9			
CT	6.4 / 9.6	13.4/13.8	3.6/5.6	5.1/8.2	9.4/8.3	11/8.4		
RI	9.2/11.6	9.9/13.8	8.1/6.4	6.9/6.9	5.0/9.5	11.1/10.9	7.9/7.1	
MA	***6.9***/8.2	9.2/7.0	***12.7/16***	13.1/14.1	8.0/***13.3***	***18.9***/17.7	***12.9/13.6***	11/***13.4***

*Red font indicates significant deviation from symmetry (Bowker's $p < 0.05$)

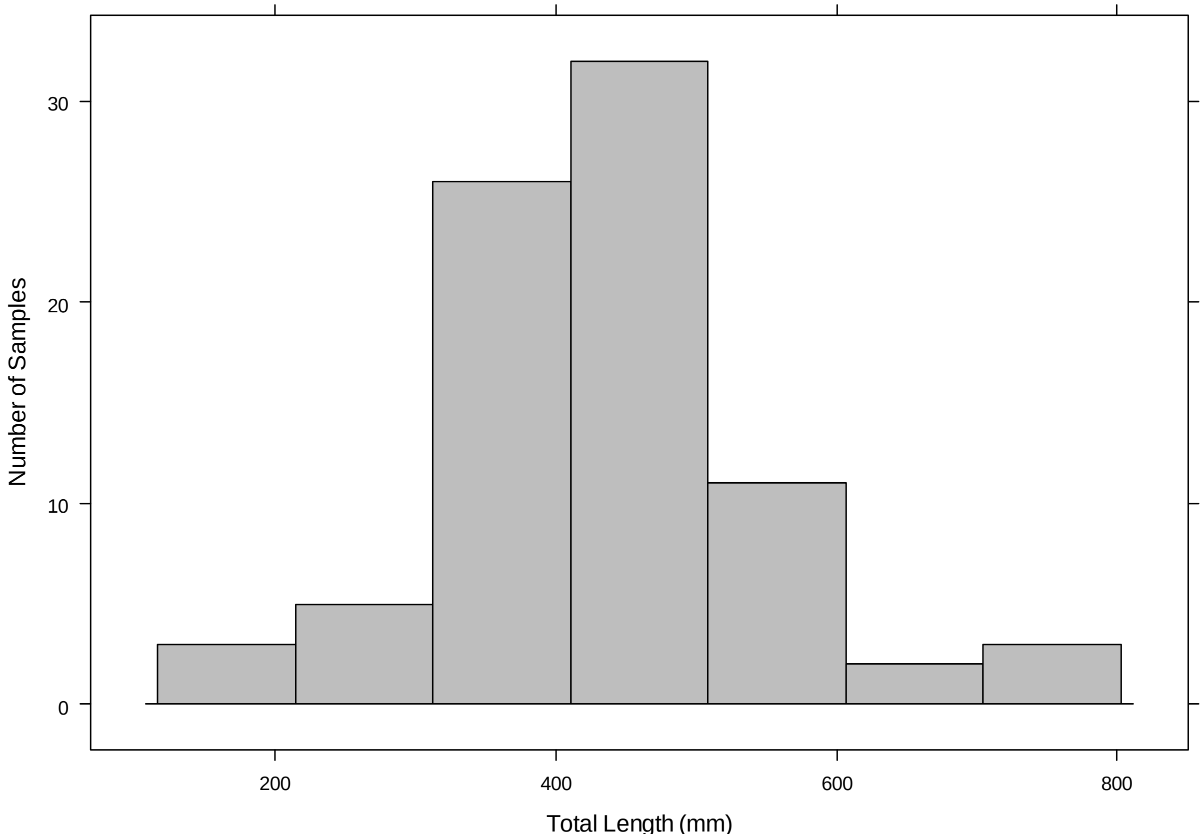


Figure 1: Length frequency distributions of fish included in the hard part exchange.

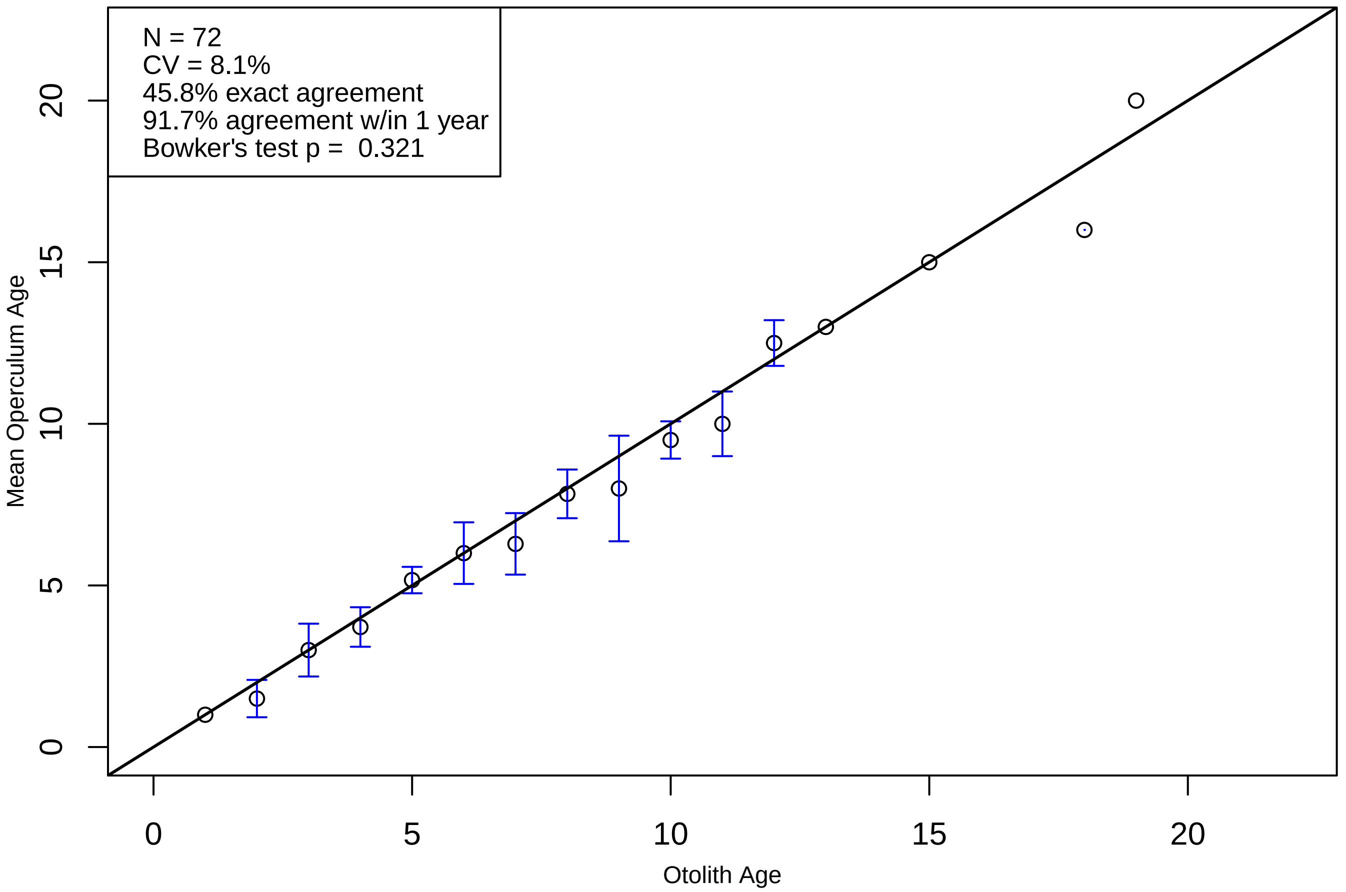


Figure 2: Mean operculum age vs. otolith age for ODU. Error bars = standard deviation.

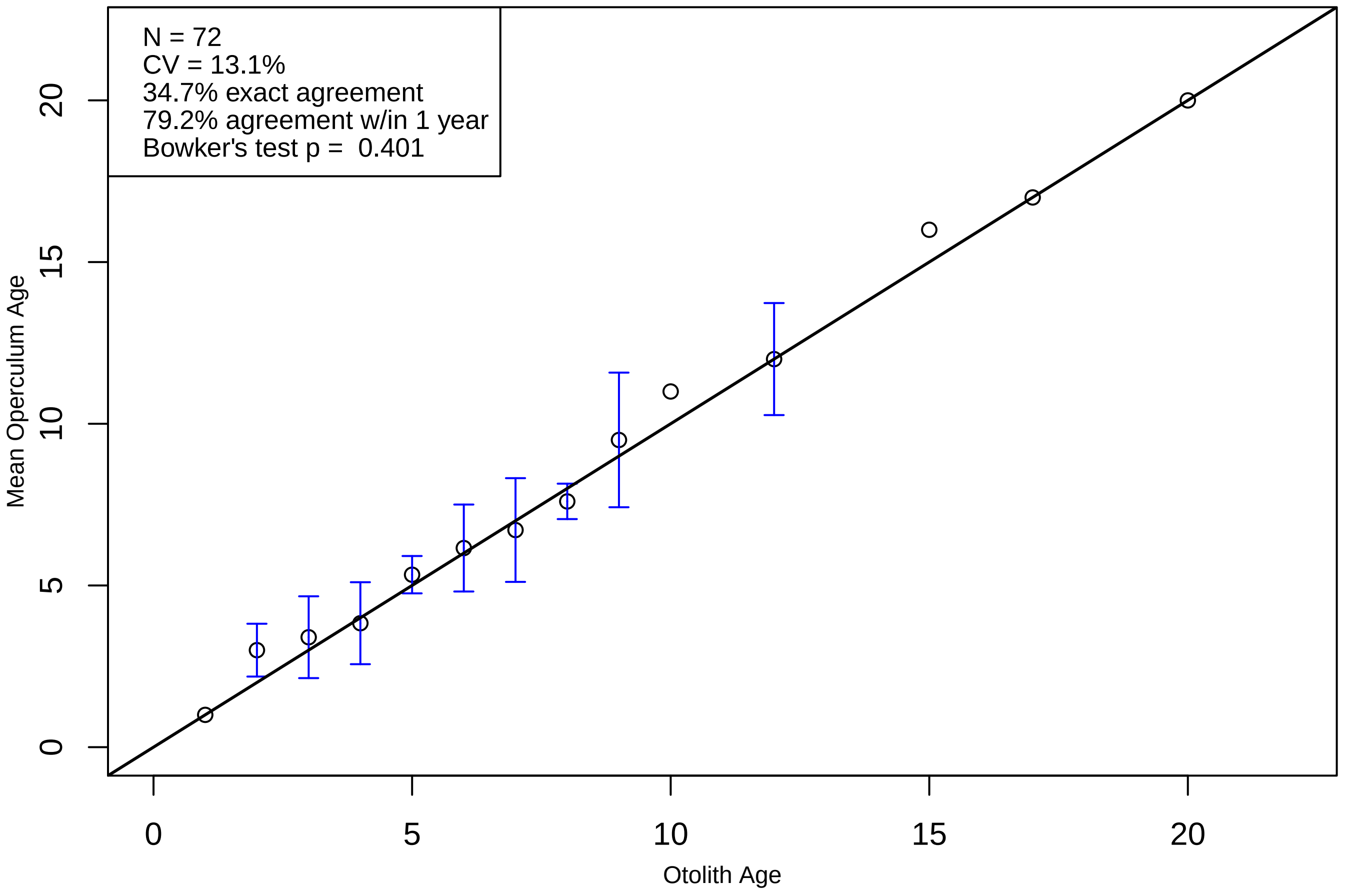


Figure 3: Mean operculum age vs. otolith age for VIMS. Error bars = standard deviation.

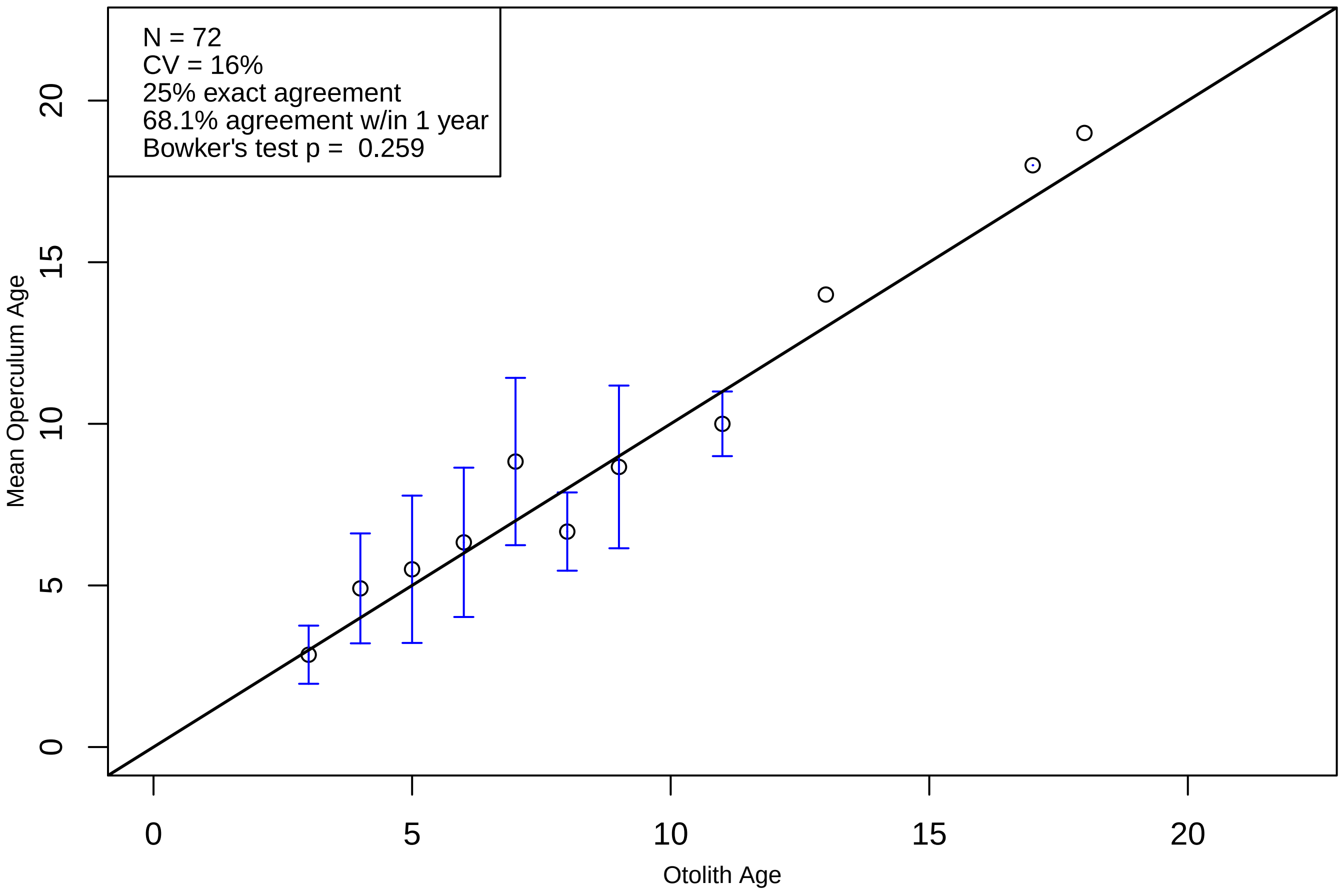


Figure 4: Mean operculum age vs. otolith age for DE. Error bars = standard deviation.

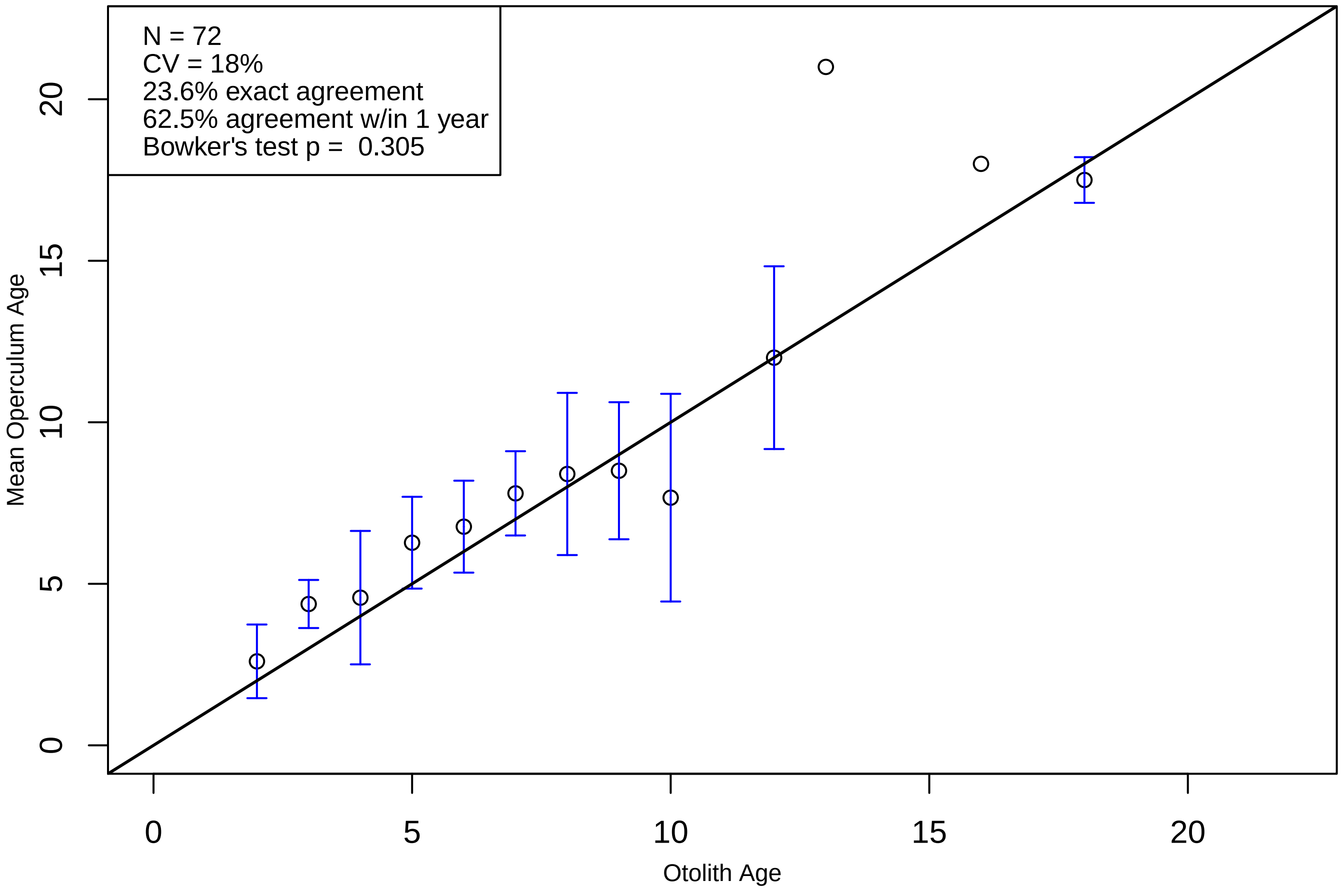


Figure 5: Mean operculum age vs. otolith age for NJ. Error bars = standard deviation.

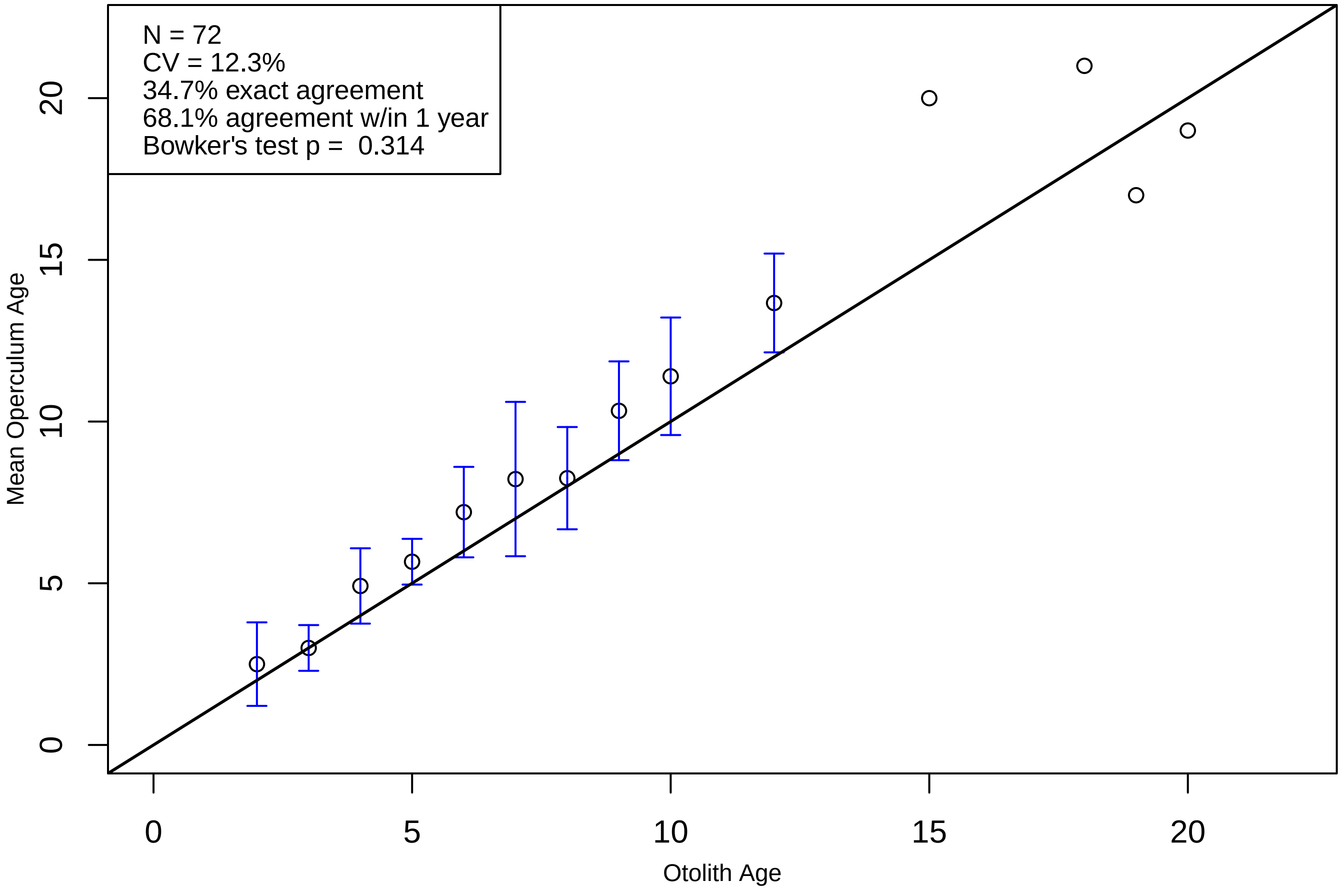


Figure 6: Mean operculum age vs. otolith age for NY. Error bars = standard deviation.

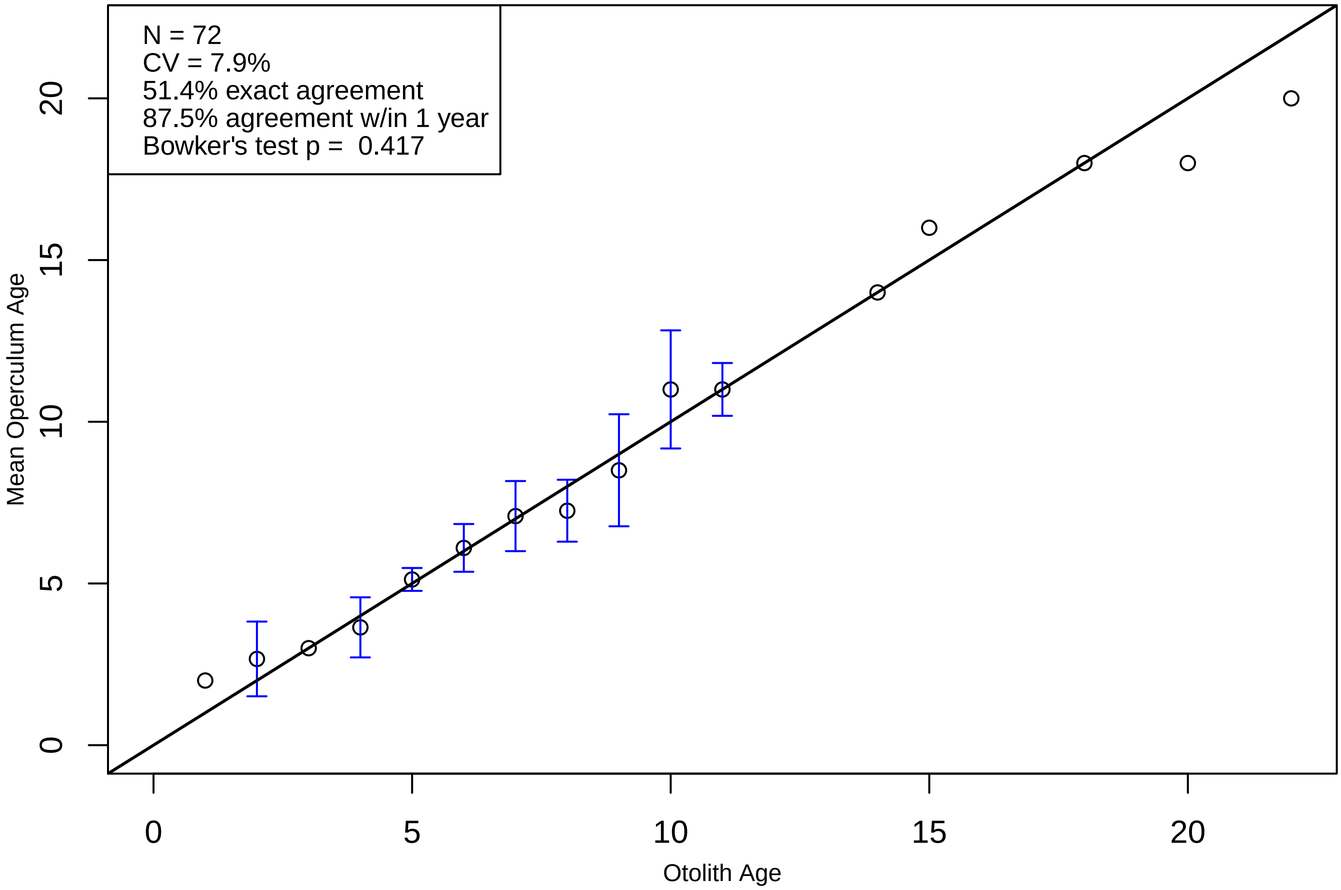


Figure 7: Mean operculum age vs. otolith age for CT. Error bars = standard deviation.

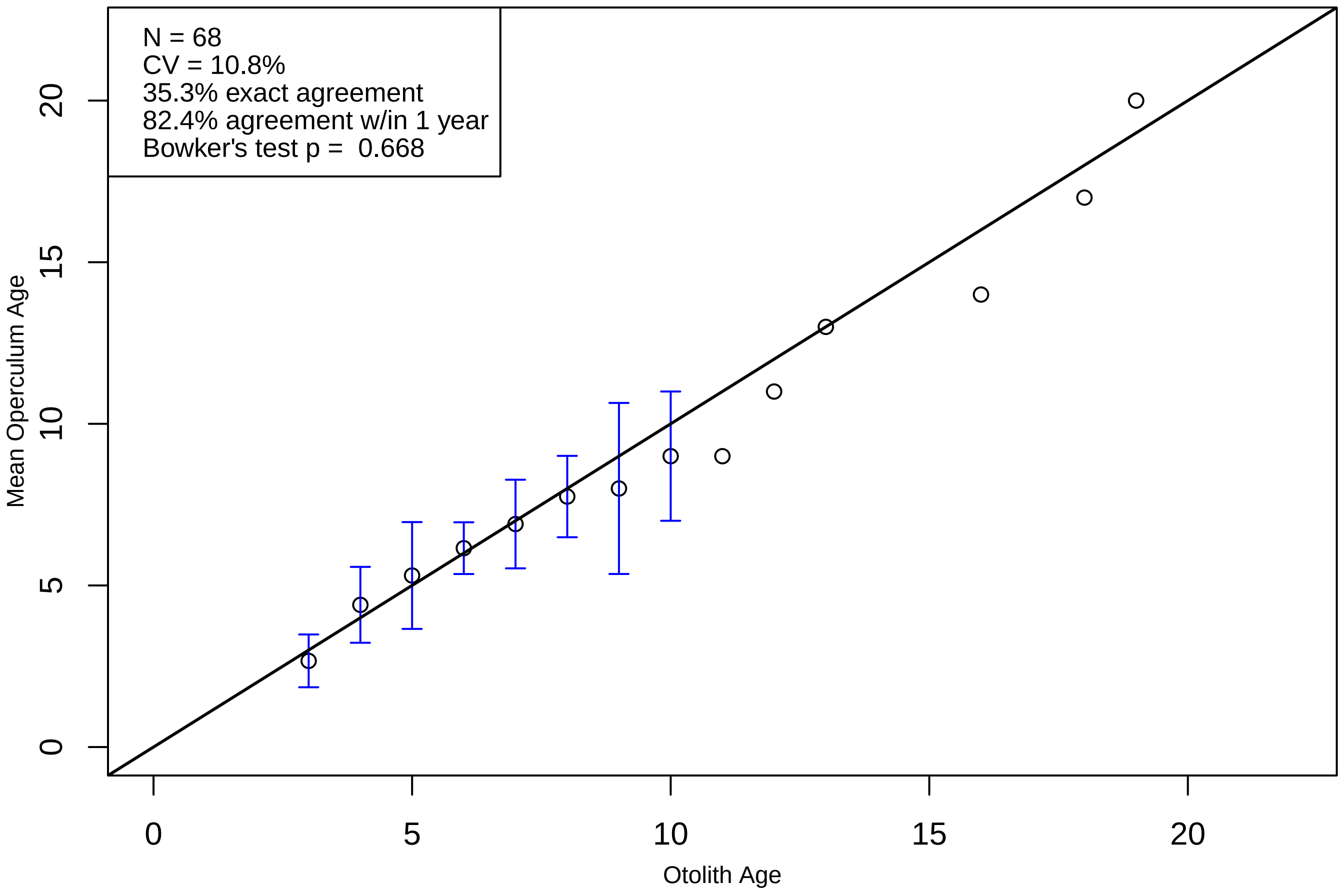


Figure 8: Mean operculum age vs. otolith age for RI. Error bars = standard deviation.

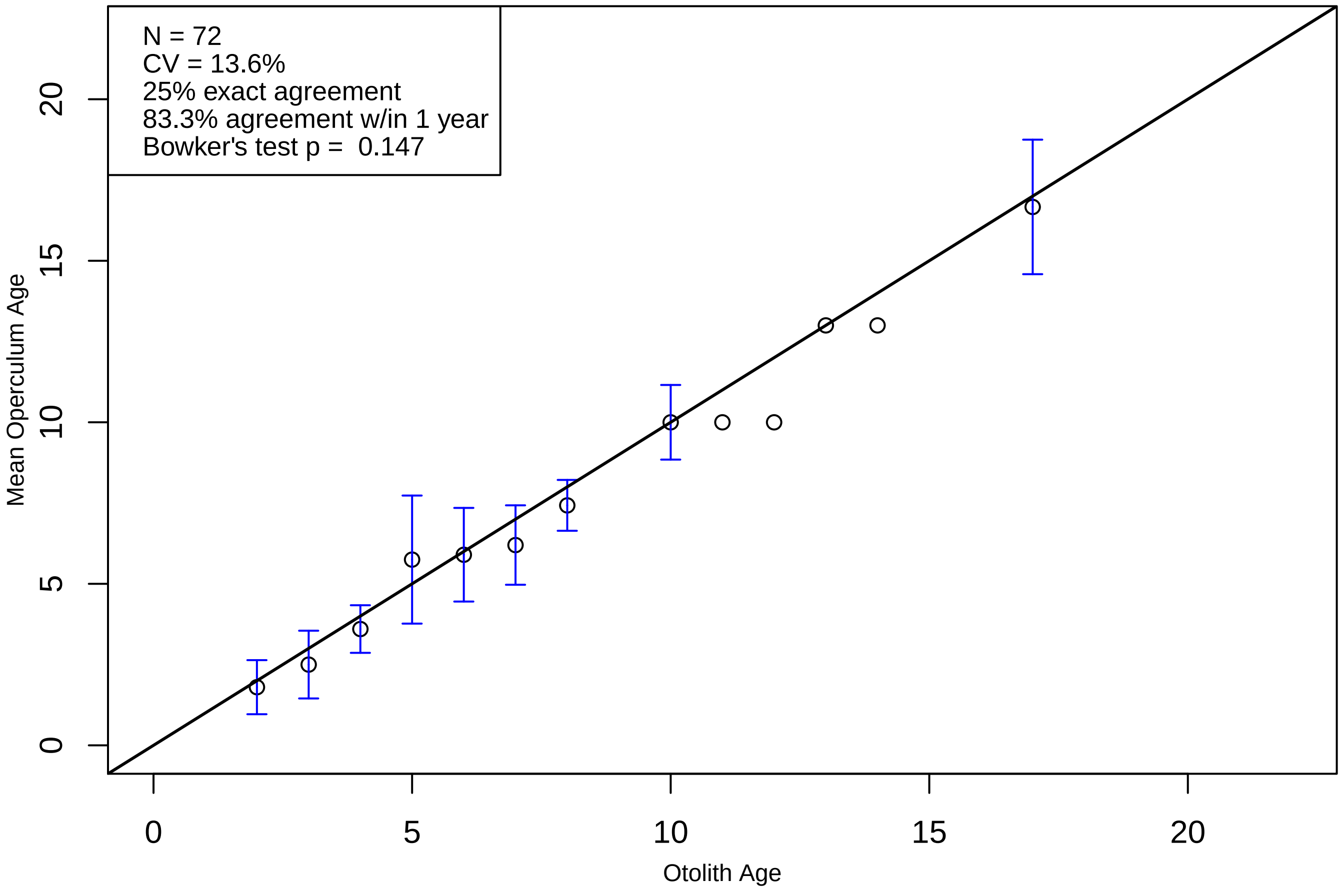


Figure 9: Mean operculum age vs. otolith age for MA. Error bars = standard deviation.

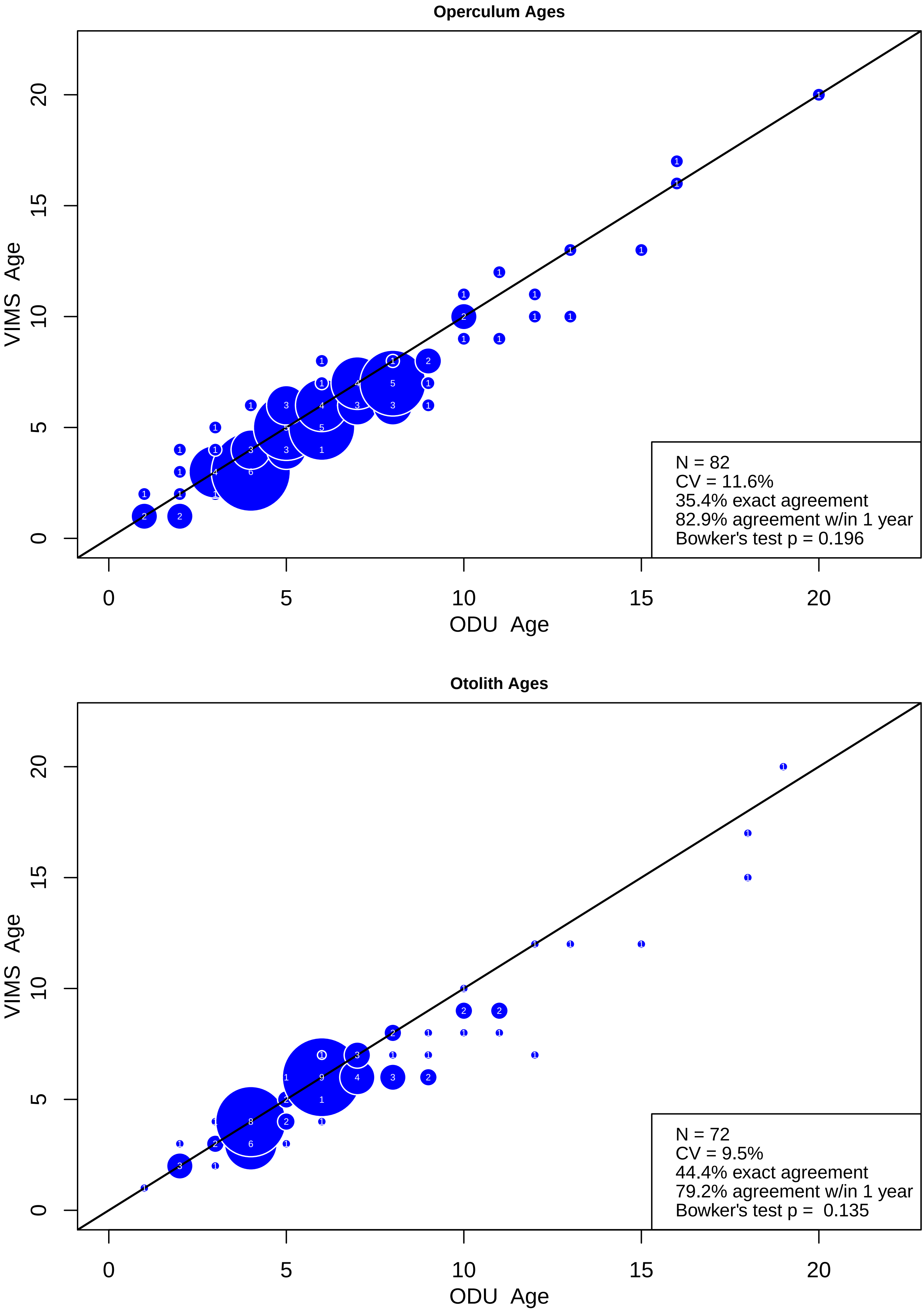


Figure 10: VIMS vs. ODU bias plots by hard part. Circles are proportional to number of observations.

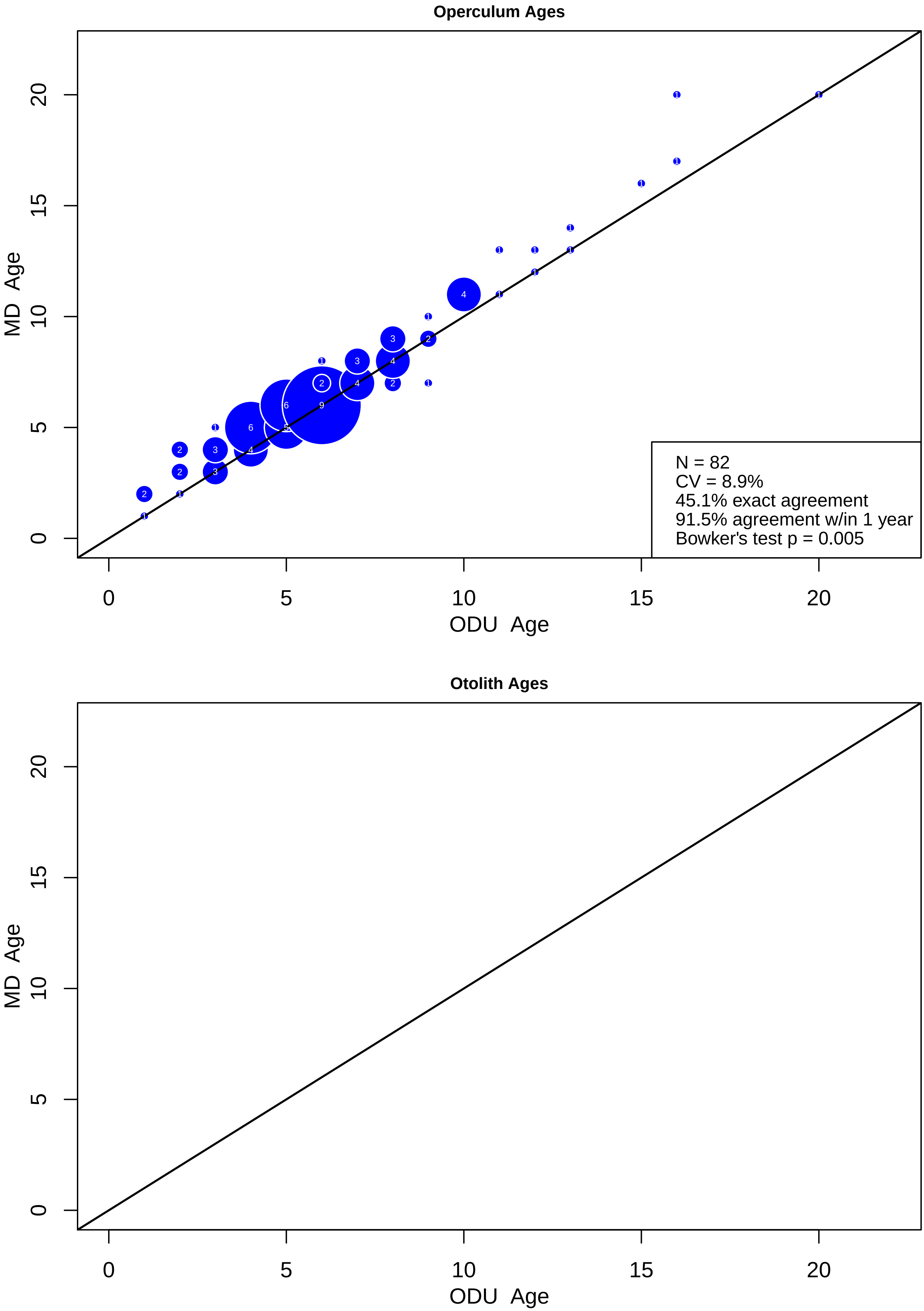


Figure 11: MD vs. ODU bias plots by hard part. Circles are proportional to number of observations.

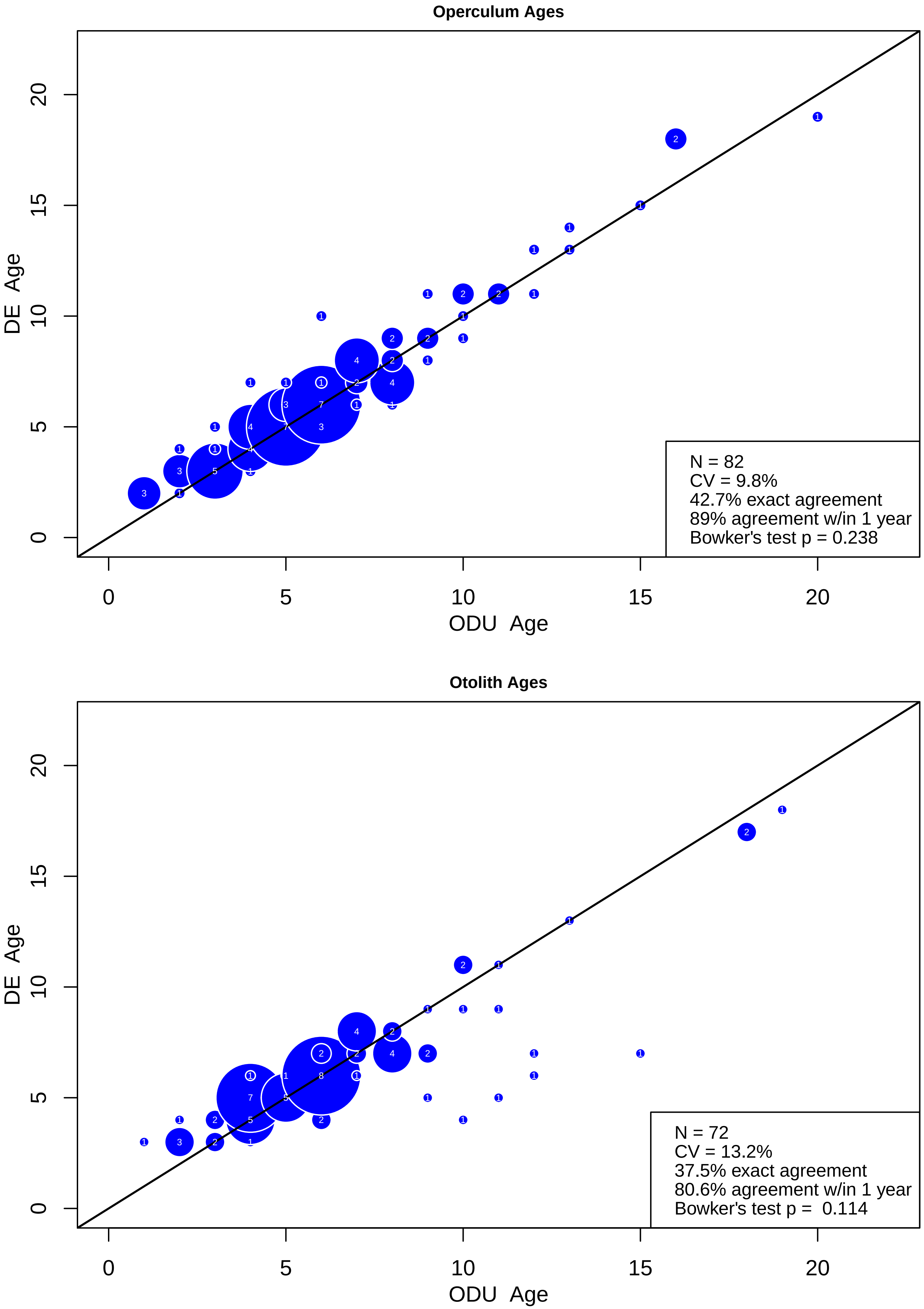


Figure 12: DE vs. ODU bias plots by hard part. Circles are proportional to number of observations.

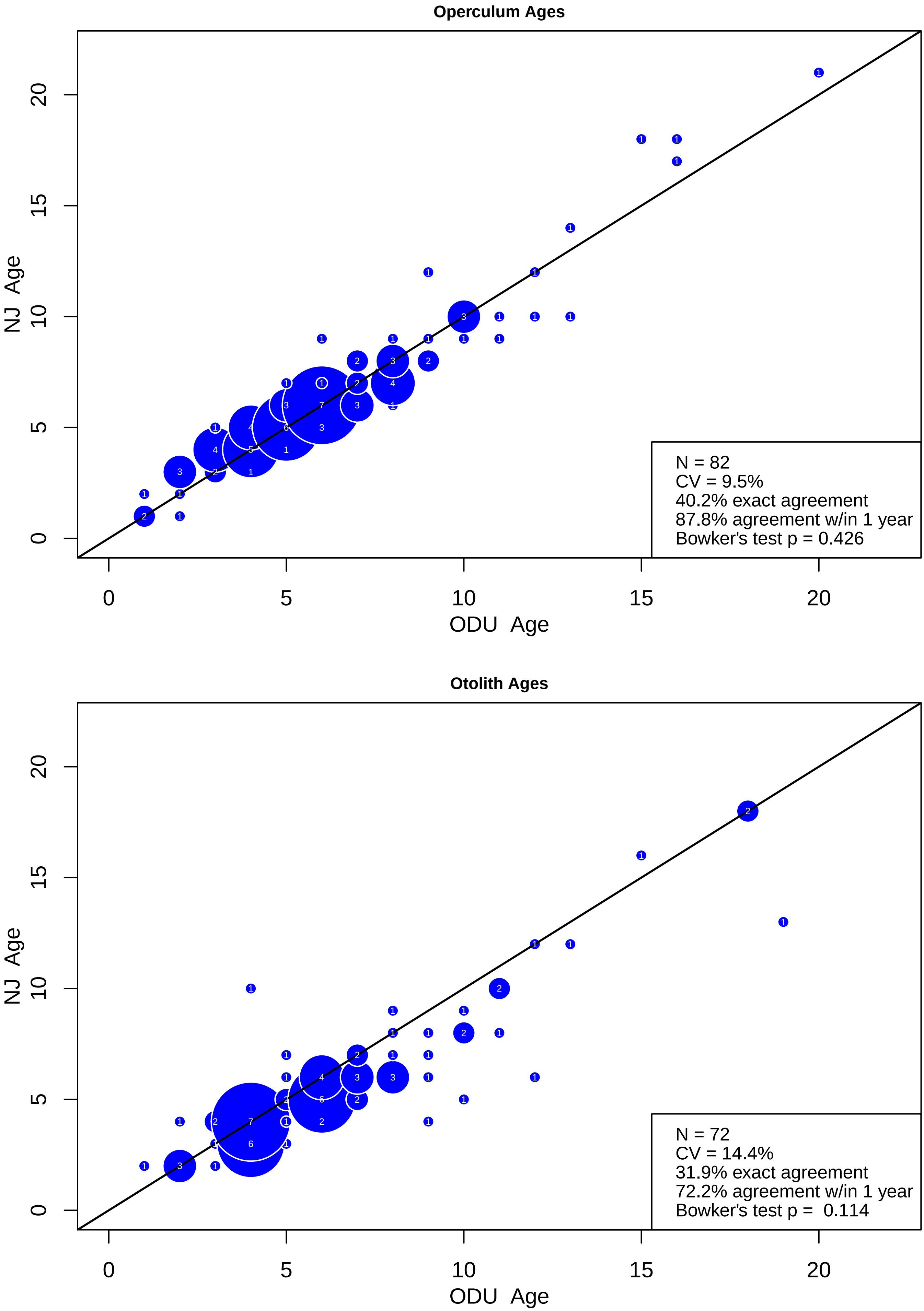
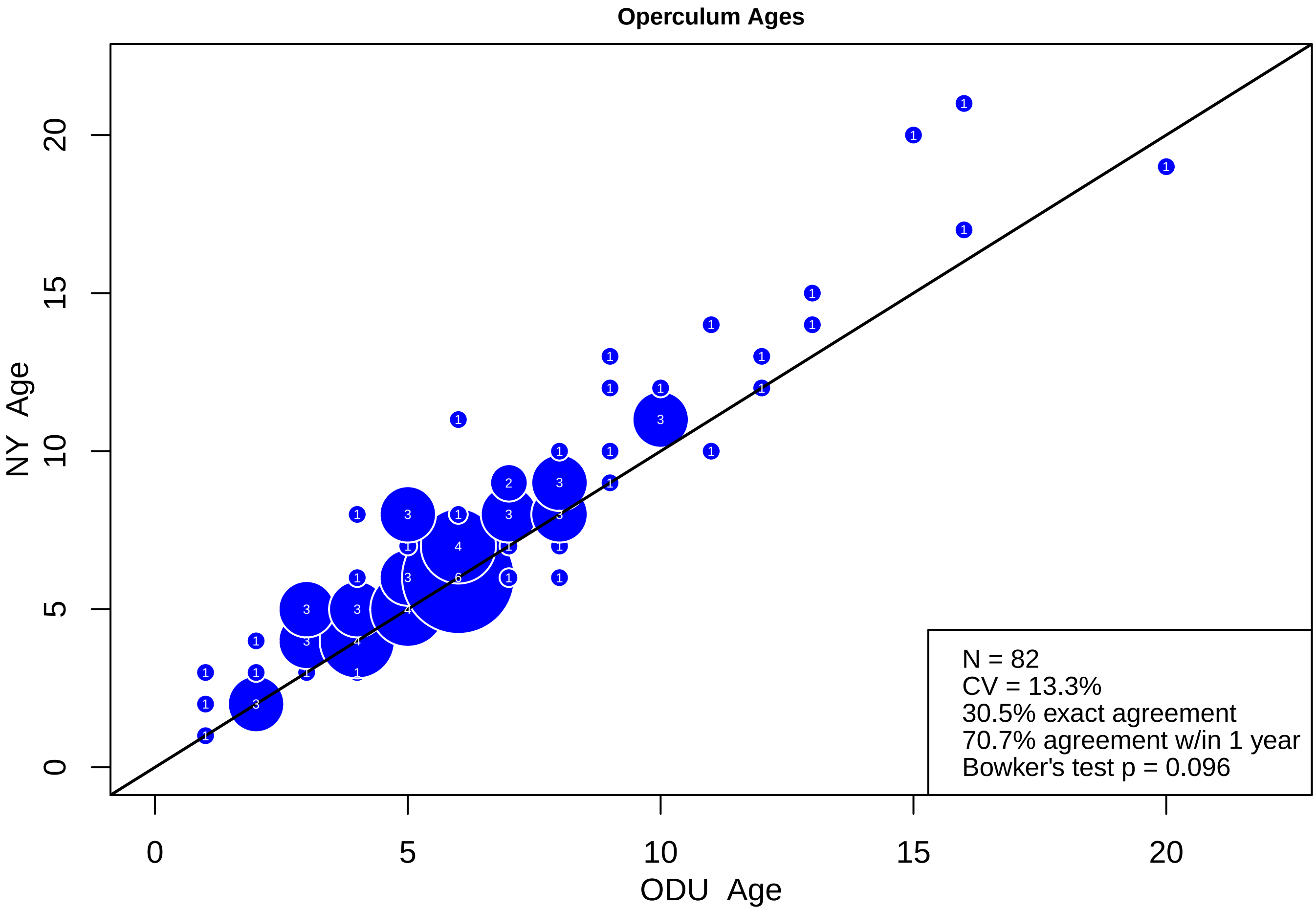


Figure 13: NJ vs. ODU bias plots by hard part. Circles are proportional to number of observations.



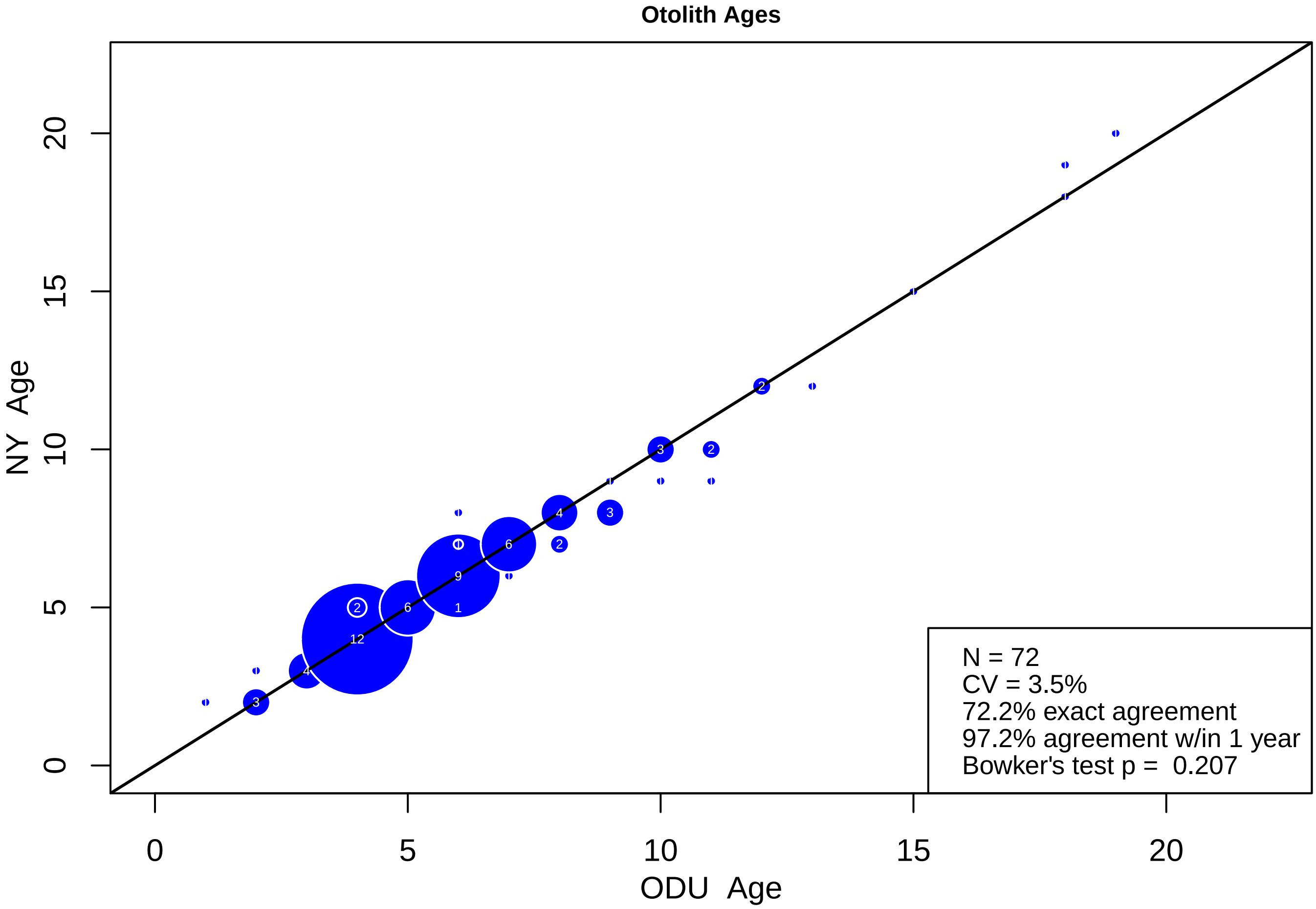
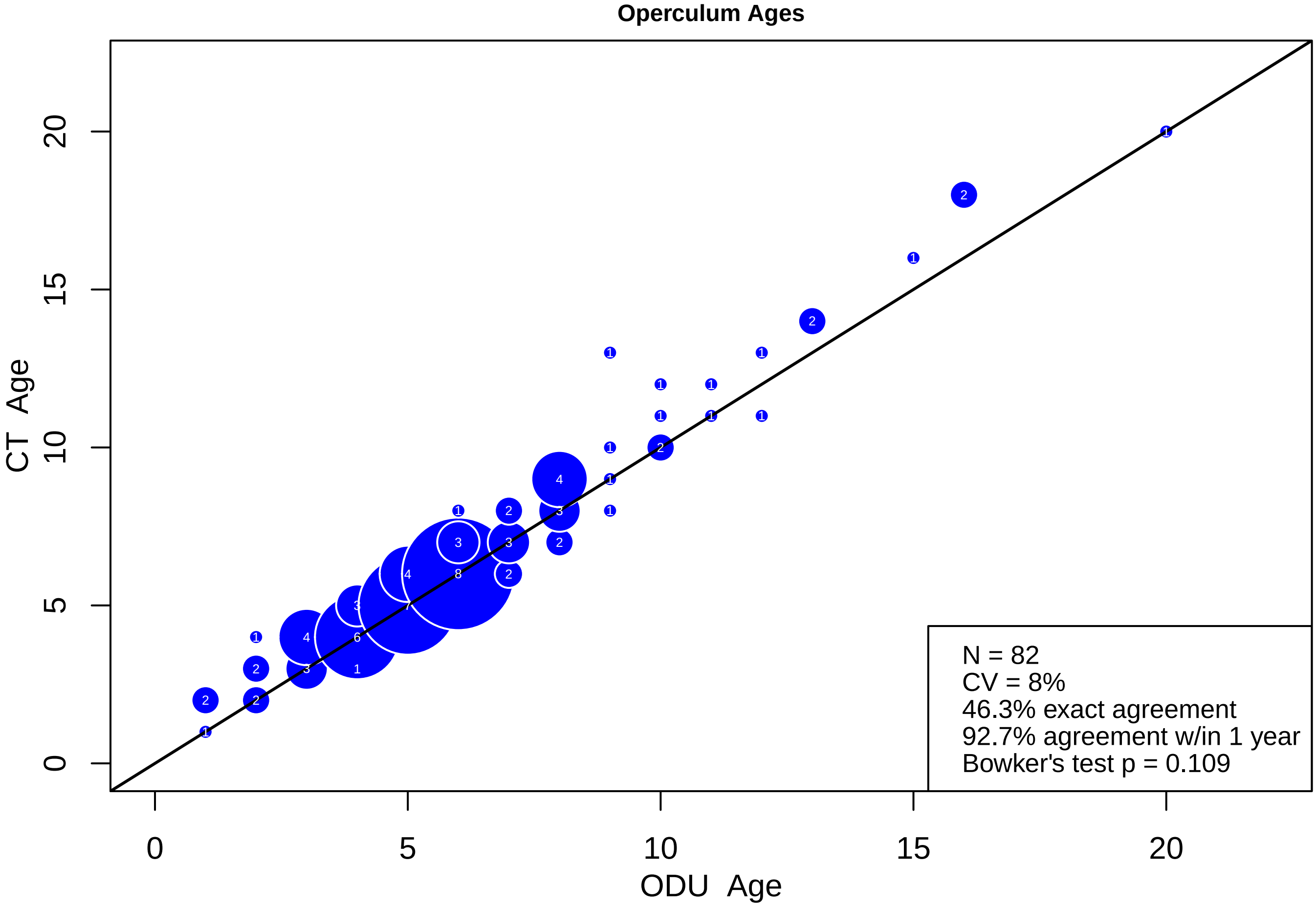


Figure 14: NY vs. ODU bias plots by hard part. Circles are proportional to number of observations.



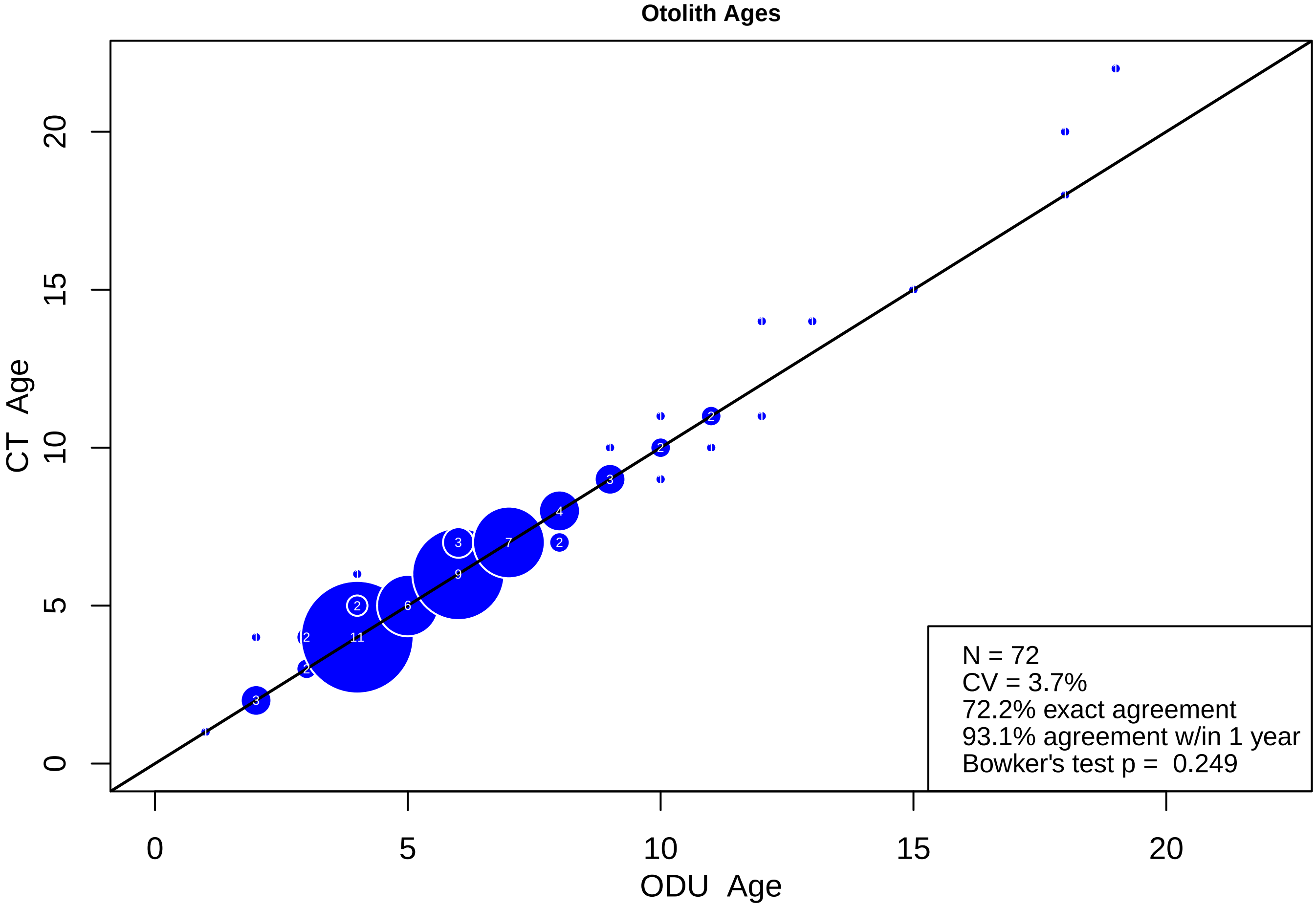
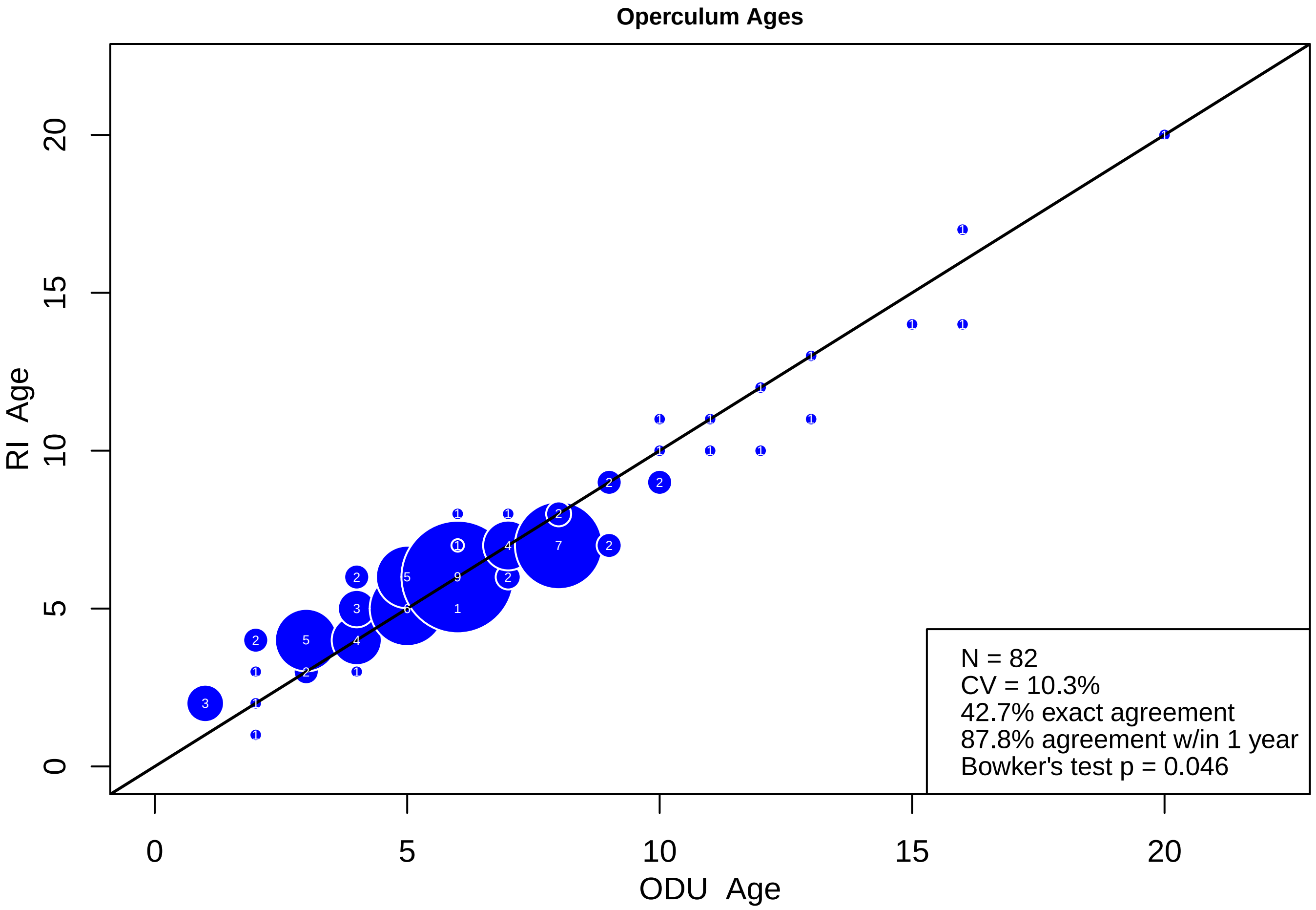


Figure 15: CT vs. ODU bias plots by hard part. Circles are proportional to number of observations.



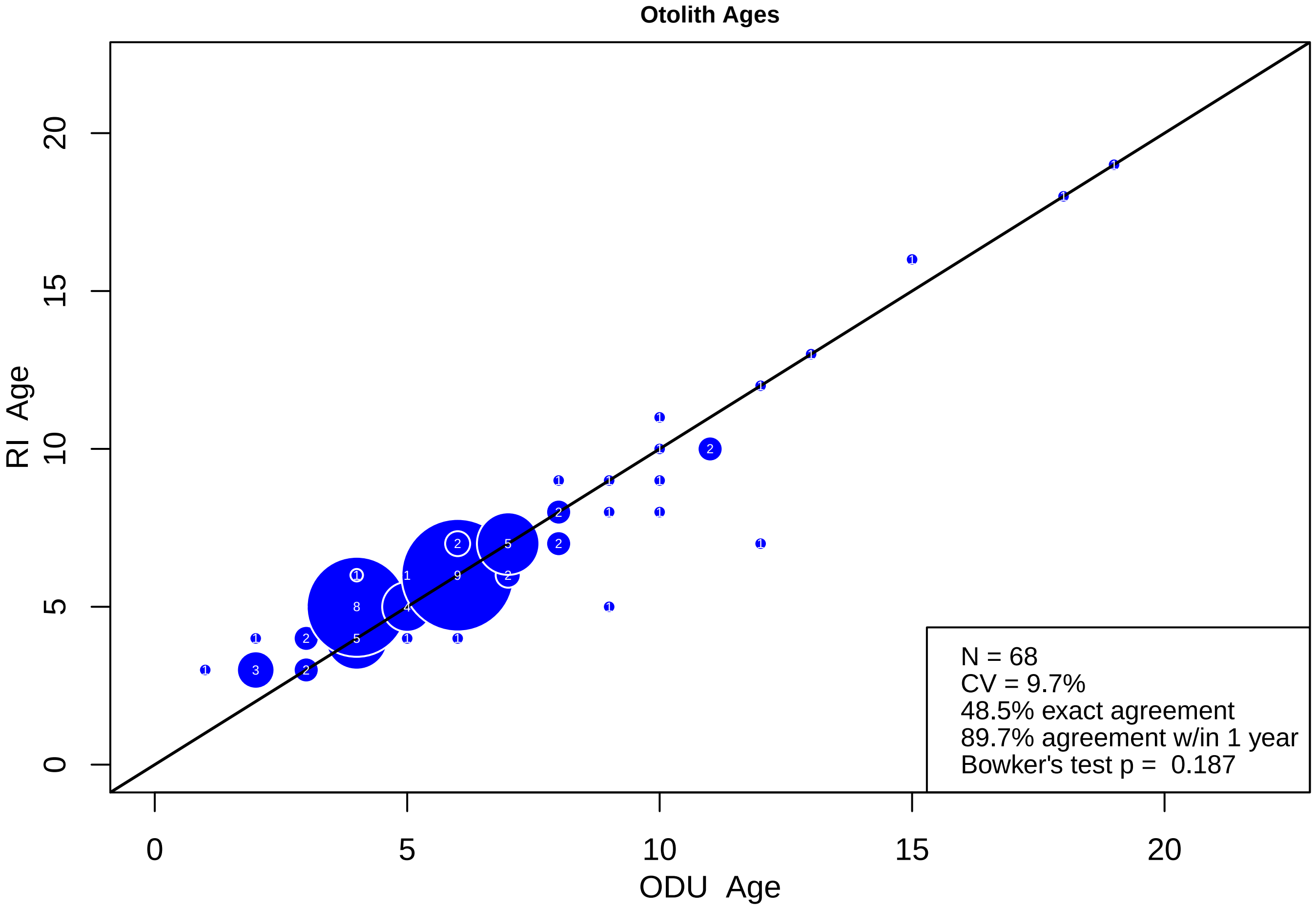
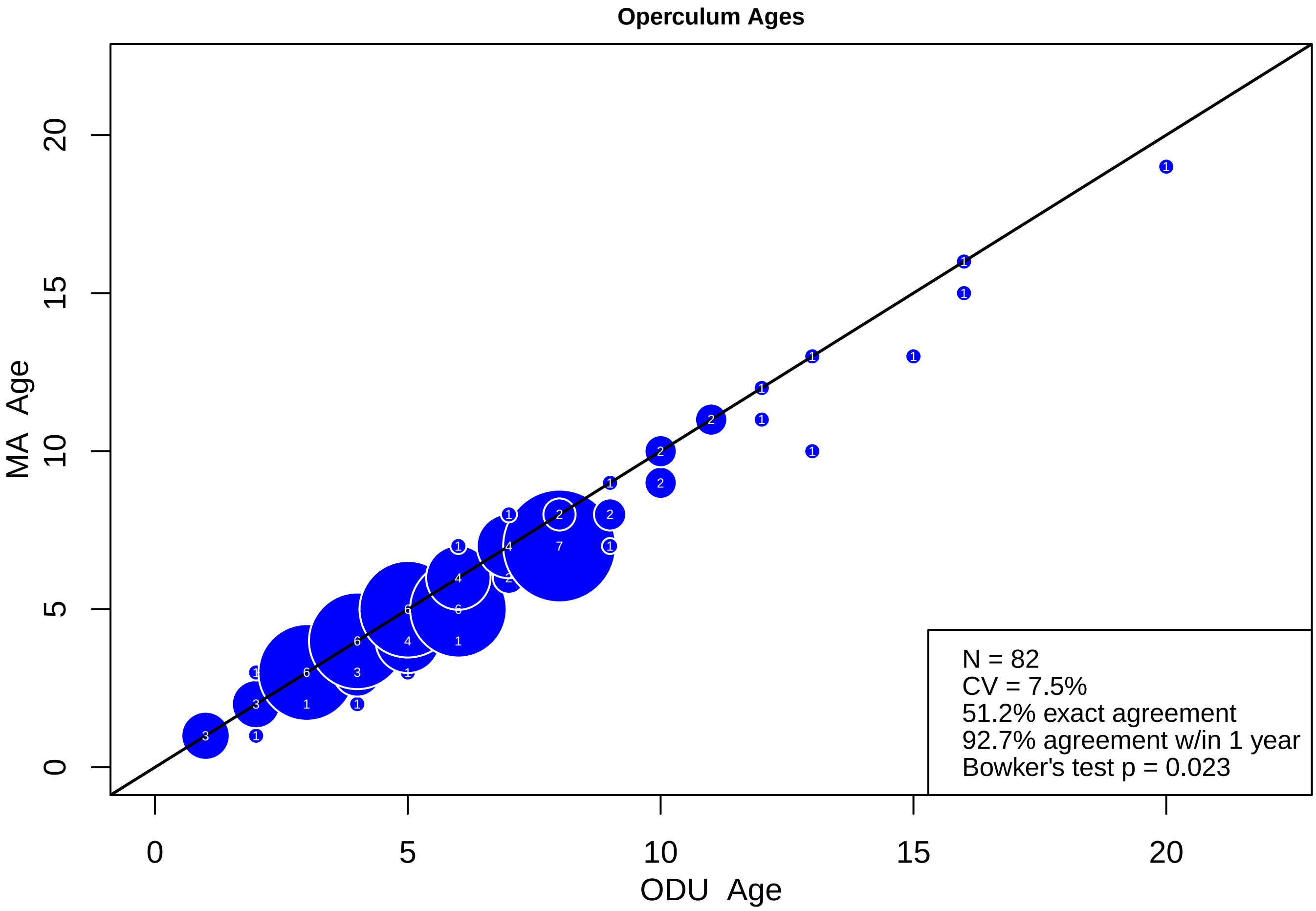


Figure 16: RI vs. ODU bias plots by hard part. Circles are proportional to number of observations.



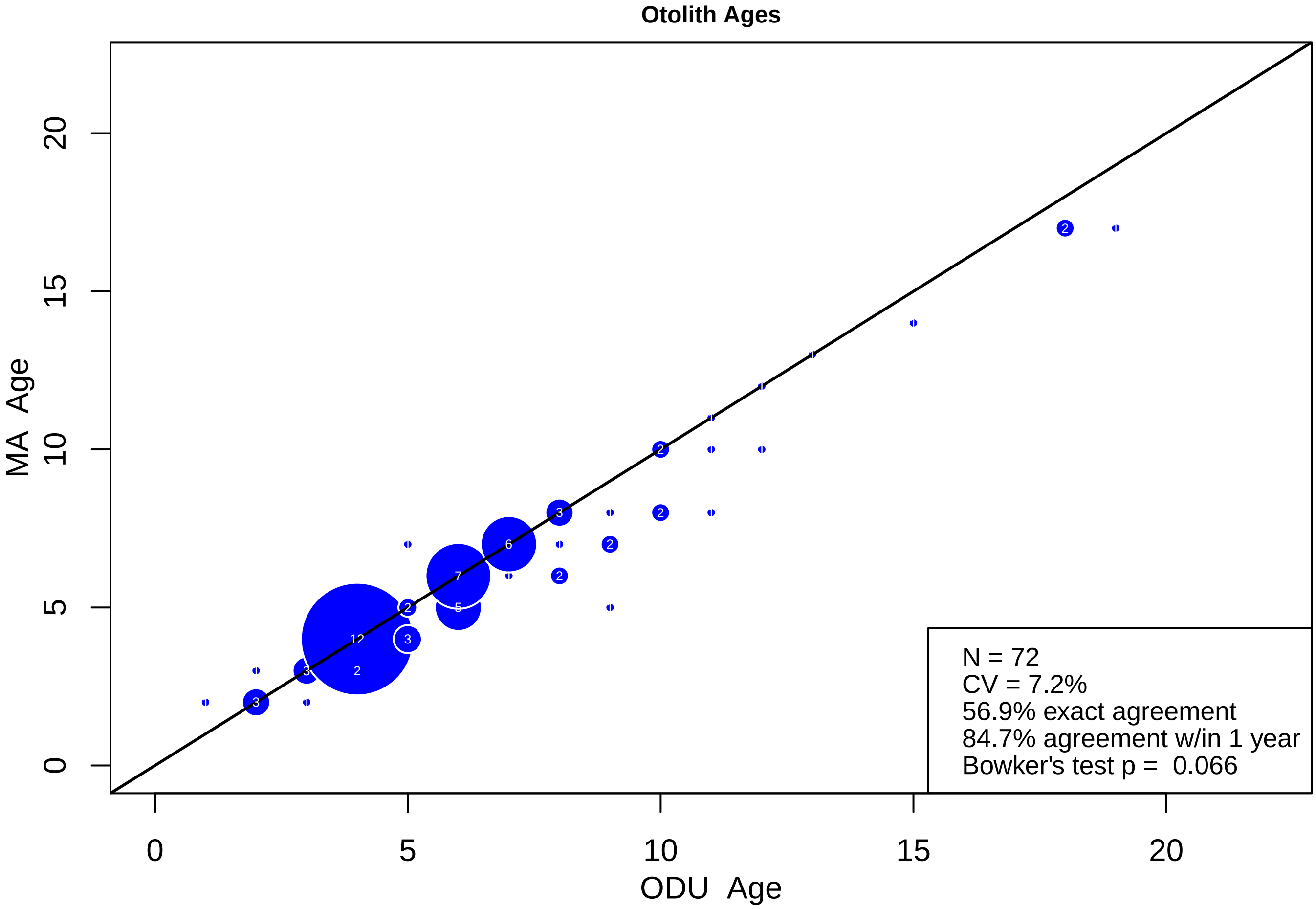
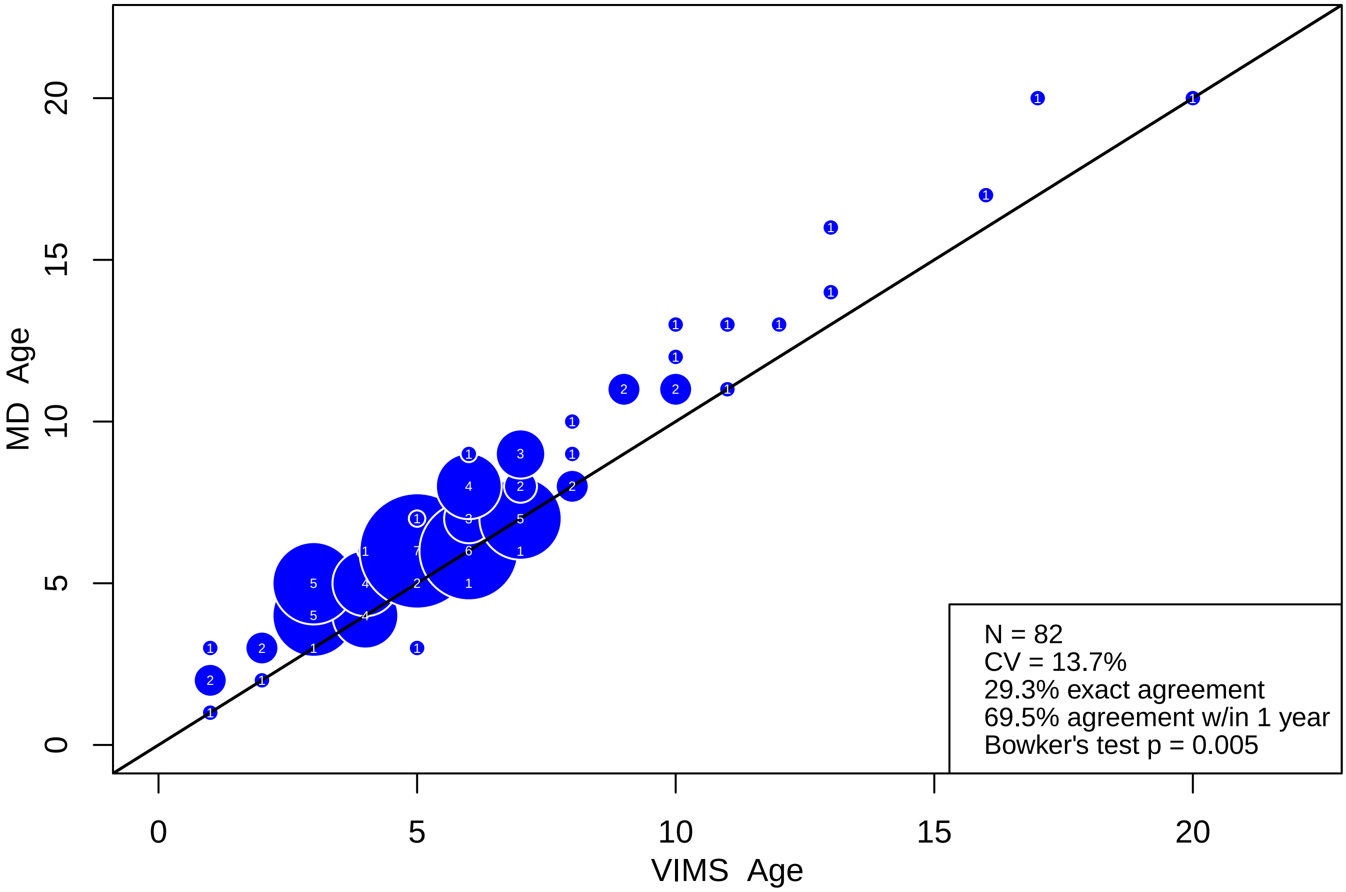


Figure 17: MA vs. ODU bias plots by hard part. Circles are proportional to number of observations.

Operculum Ages



Otolith Ages

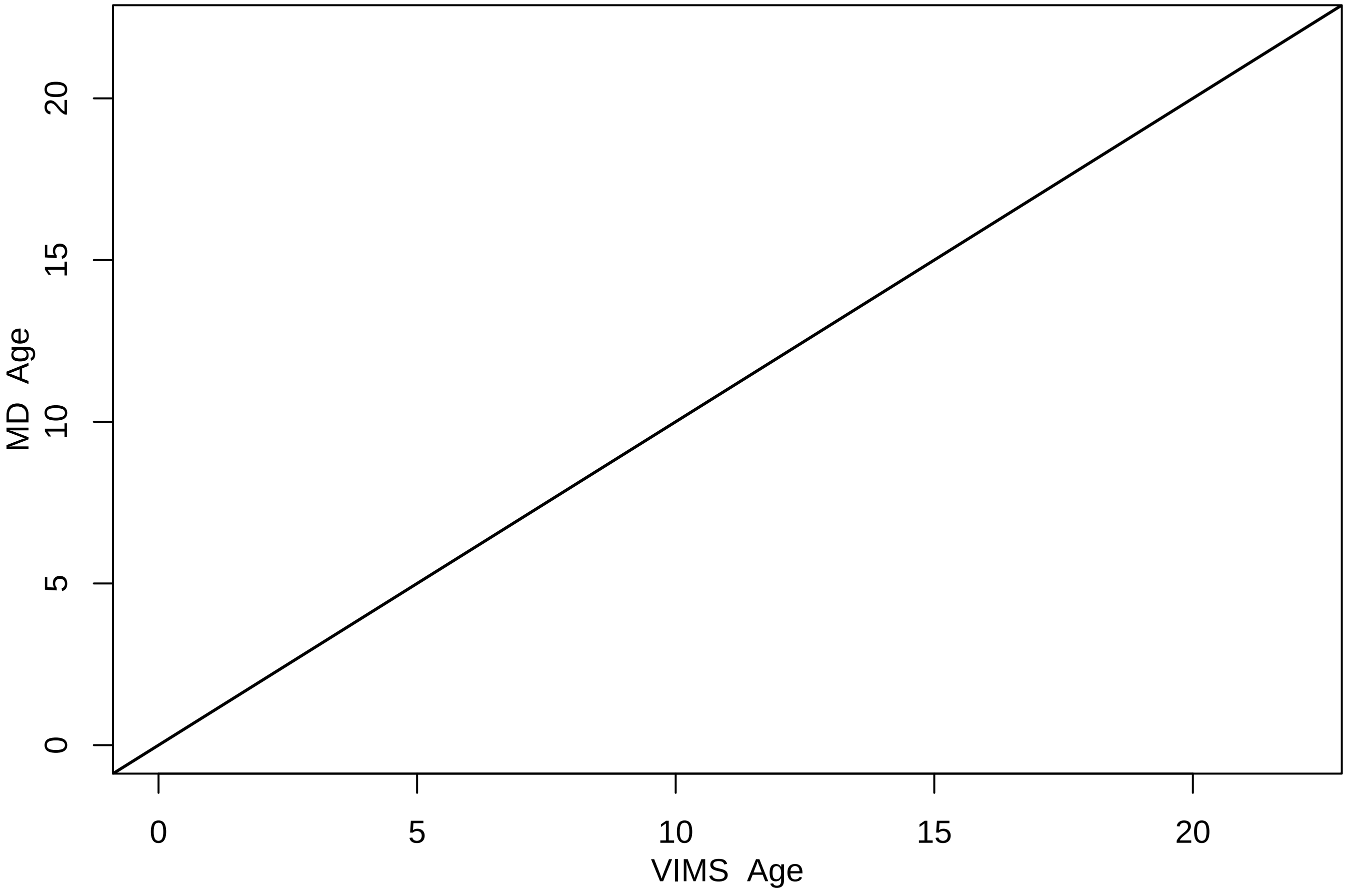
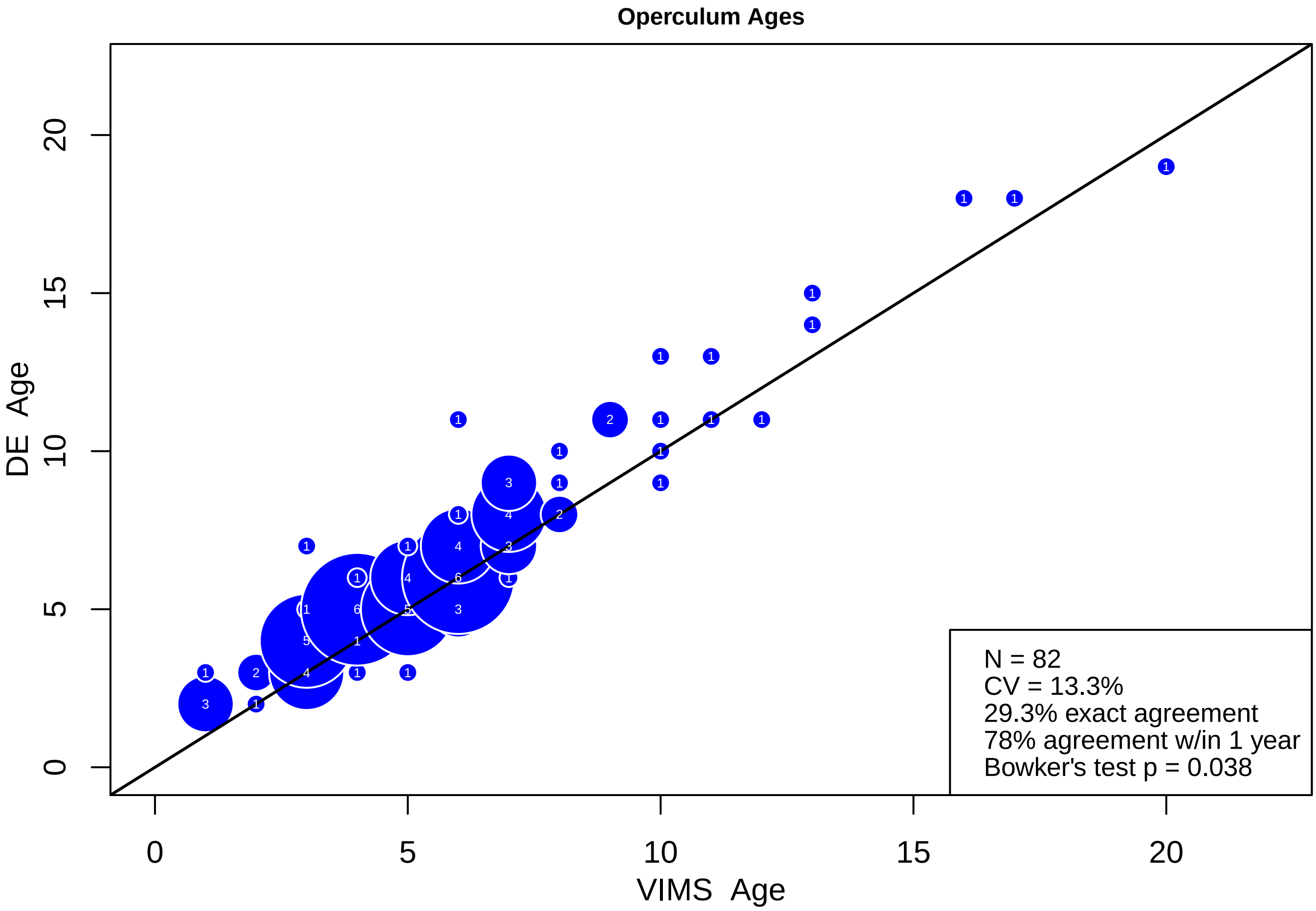


Figure 18: MD vs. VIMS bias plots by hard part. Circles are proportional to number of observations.



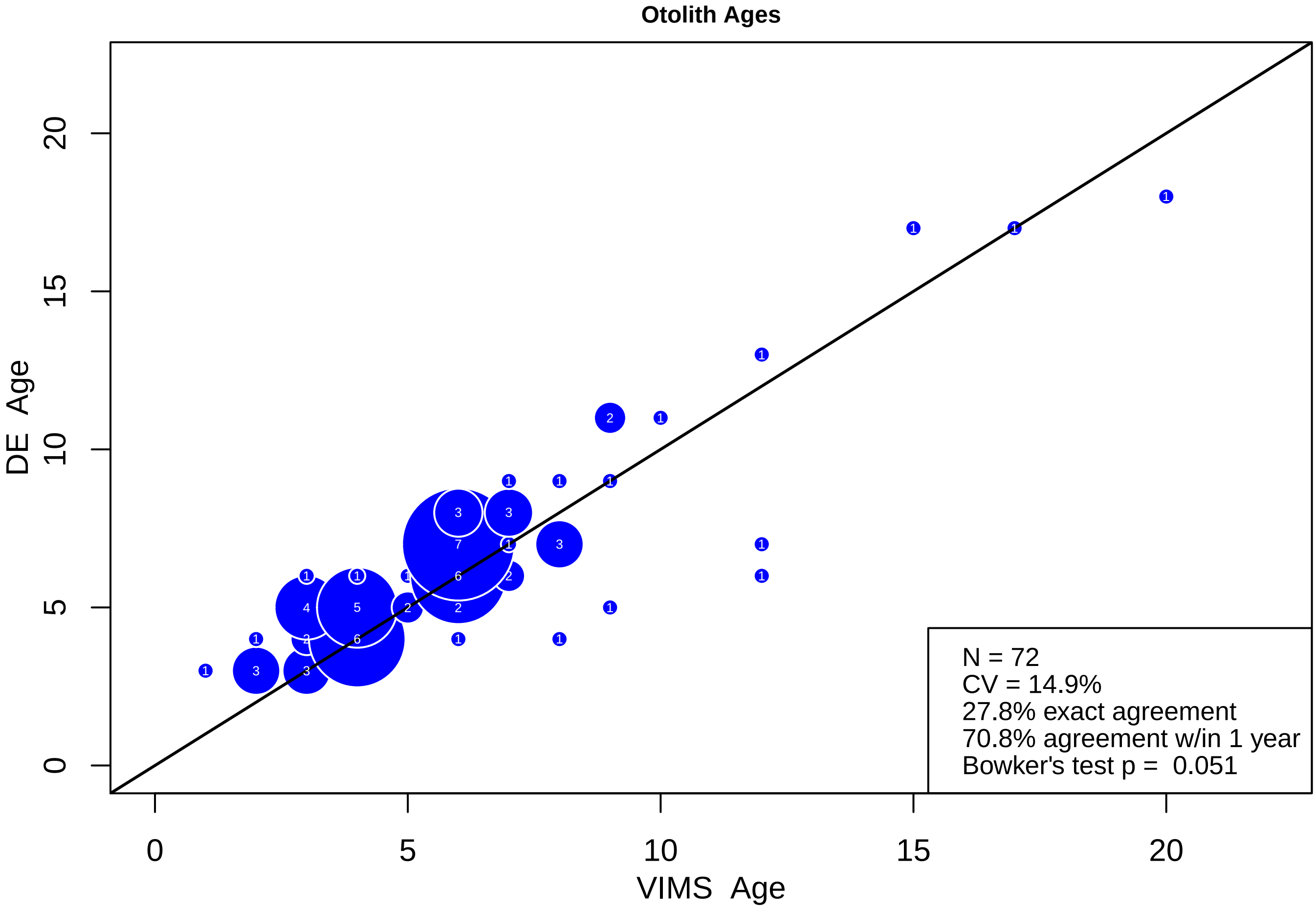
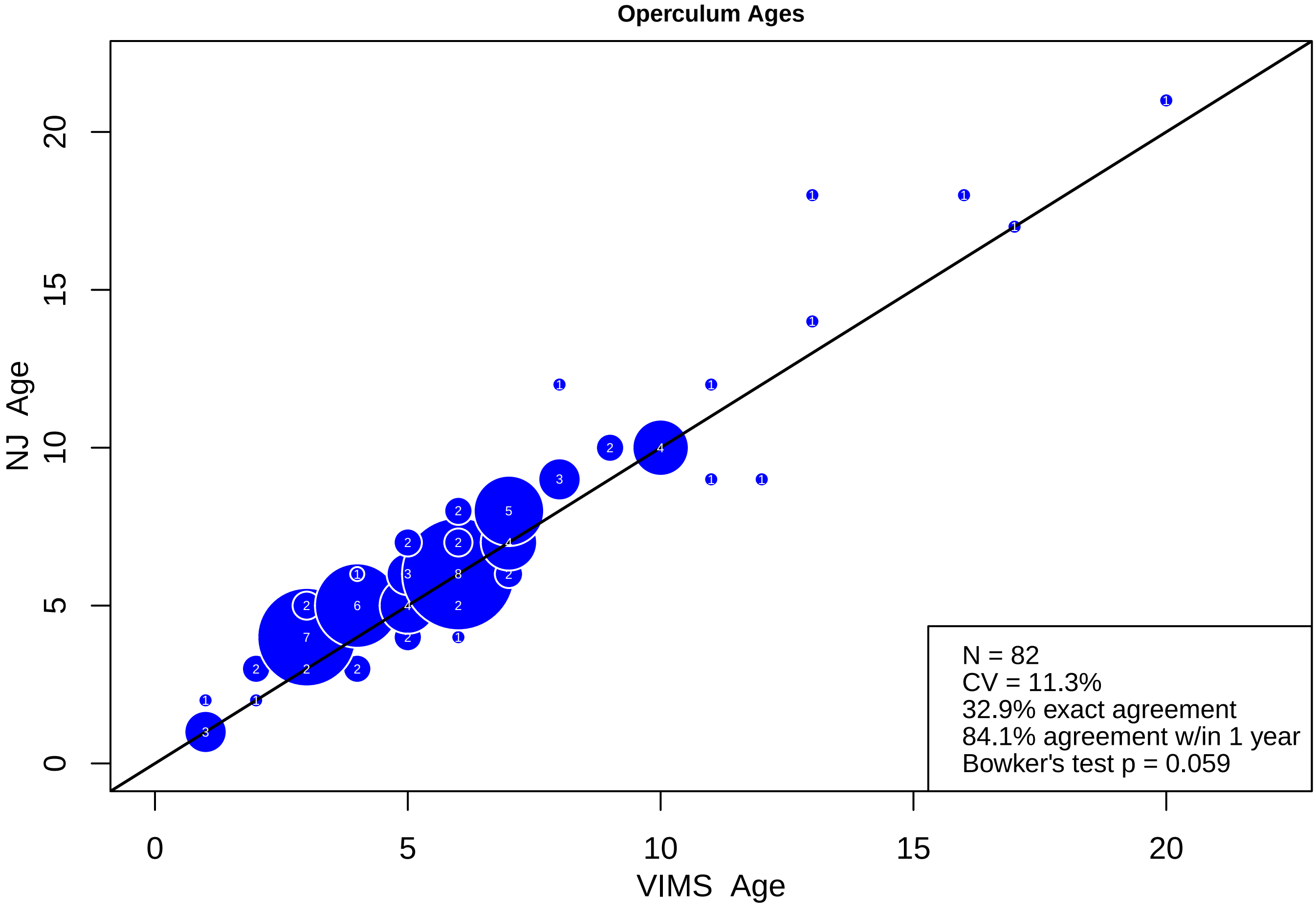


Figure 19: DE vs. VIMS bias plots by hard part. Circles are proportional to number of observations.



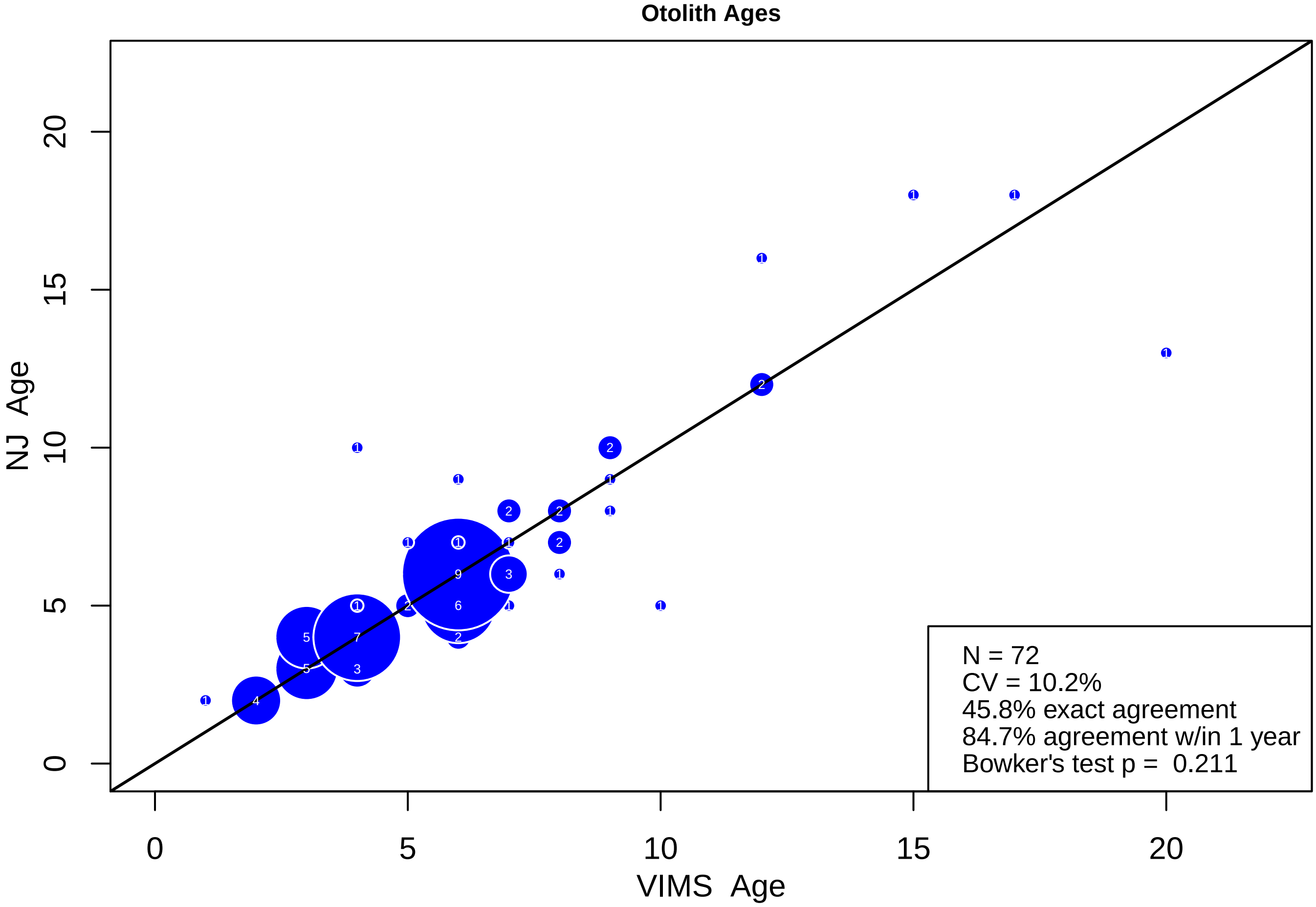
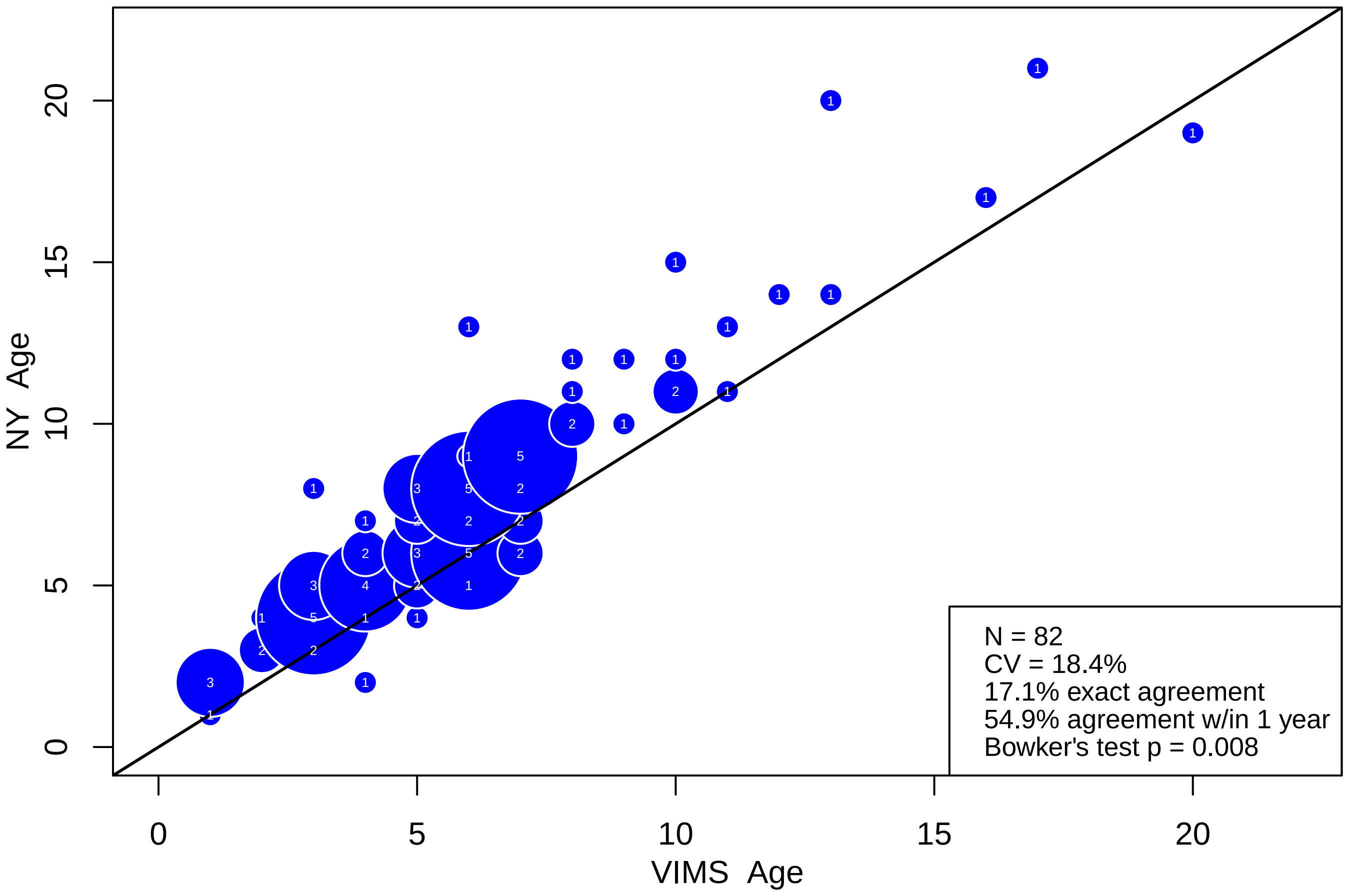


Figure 20: NJ vs. VIMS bias plots by hard part. Circles are proportional to number of observations.

Operculum Ages



Otolith Ages

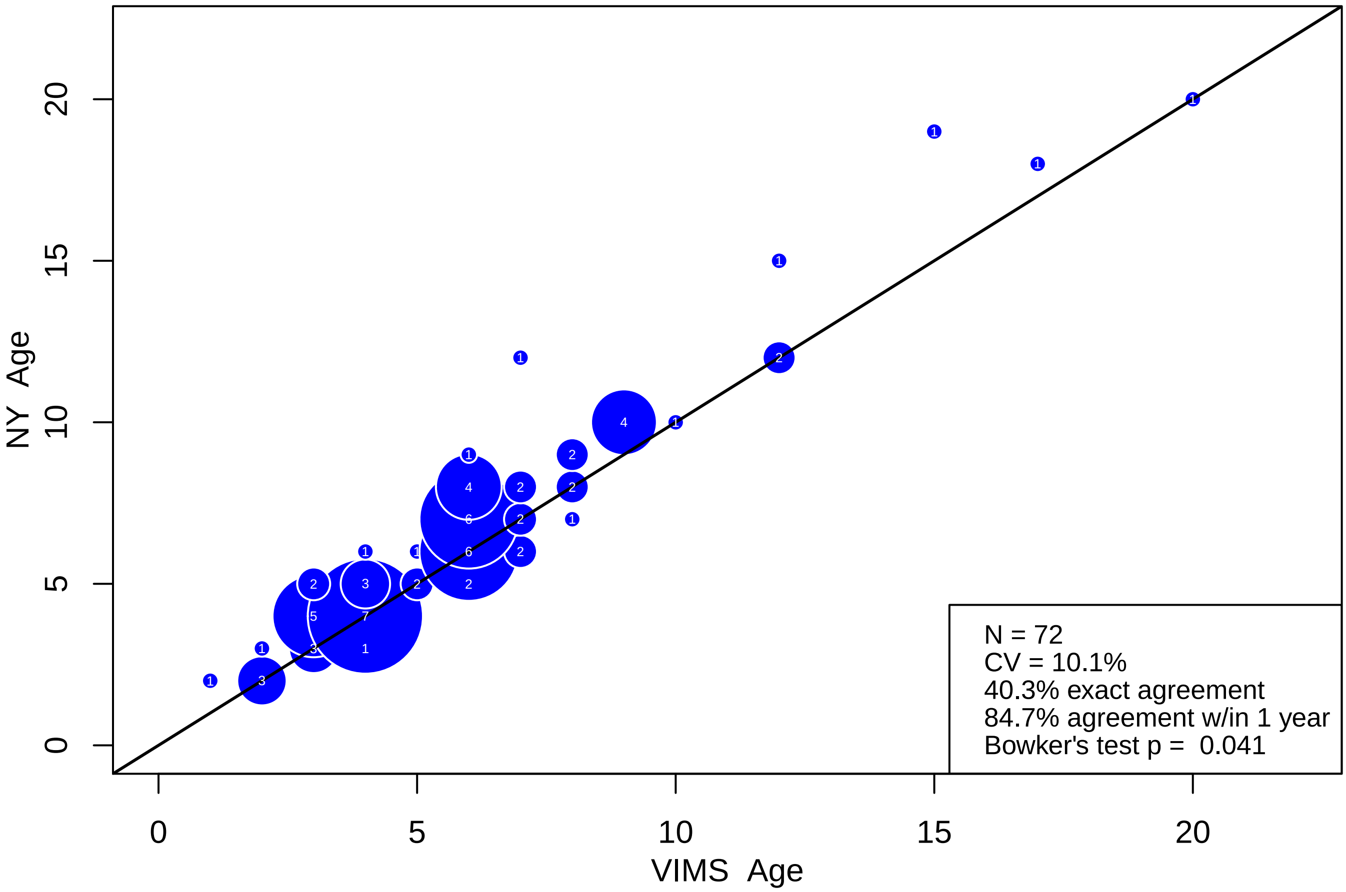


Figure 21: NY vs. VIMS bias plots by hard part. Circles are proportional to number of observations.

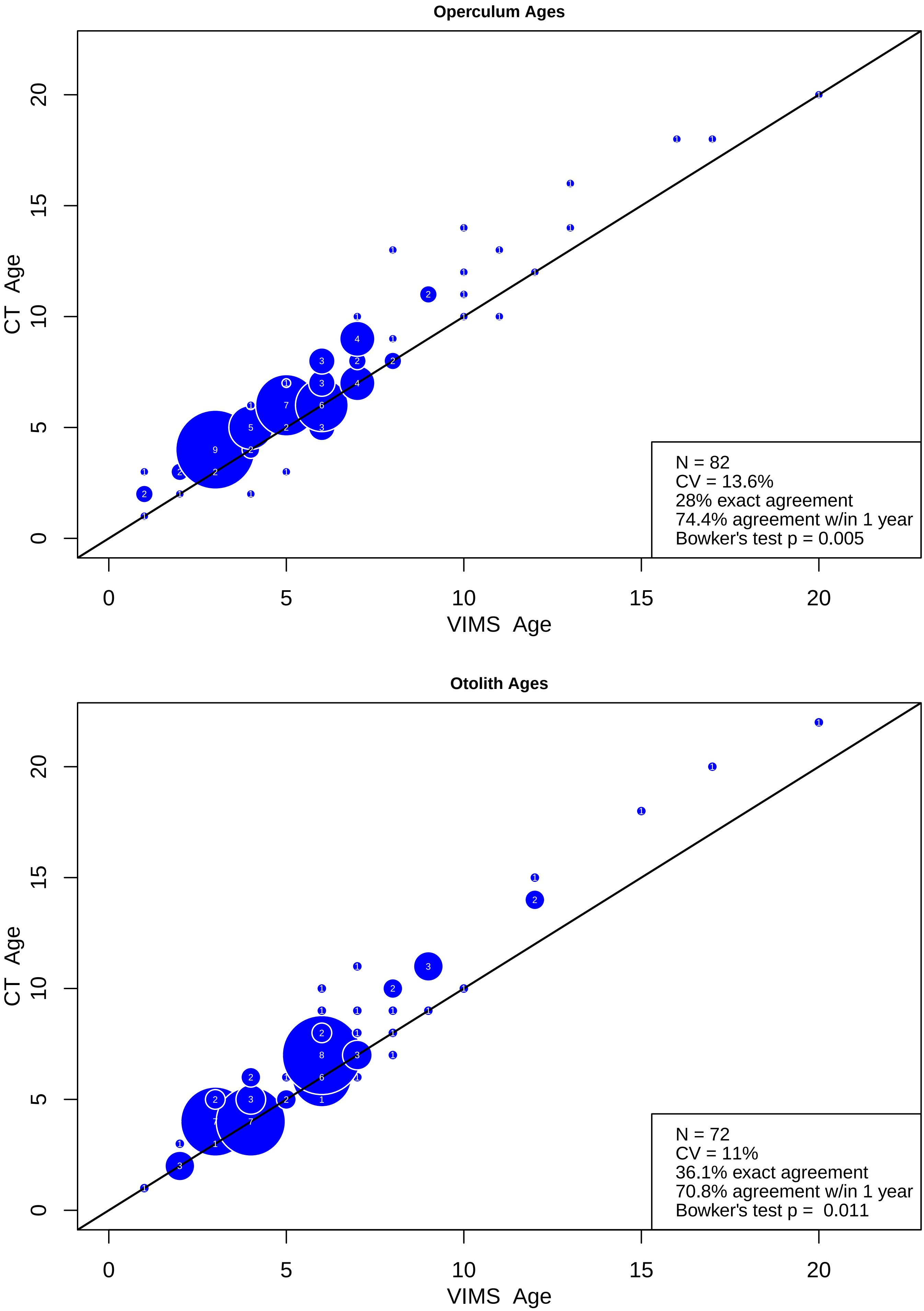
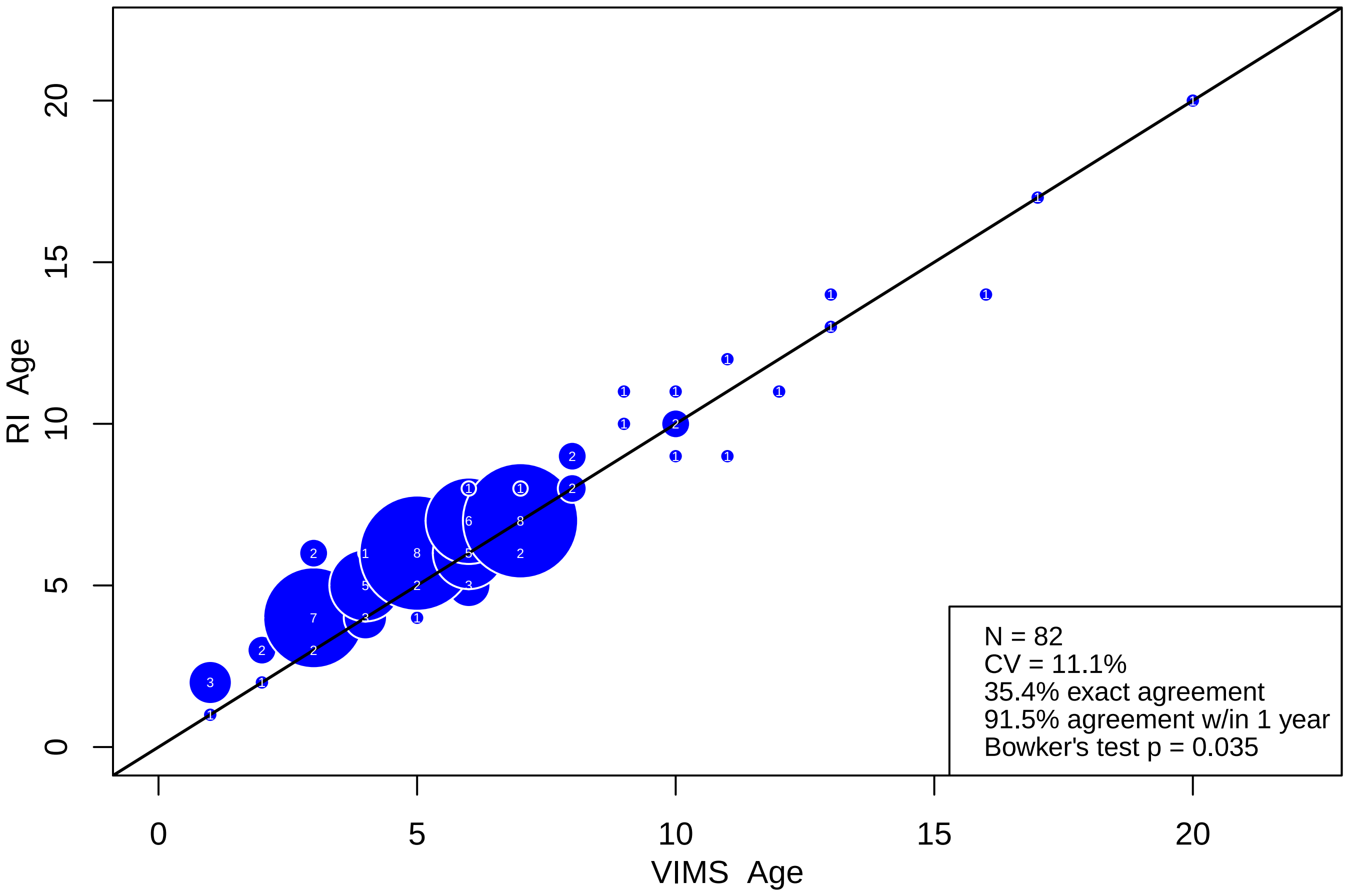
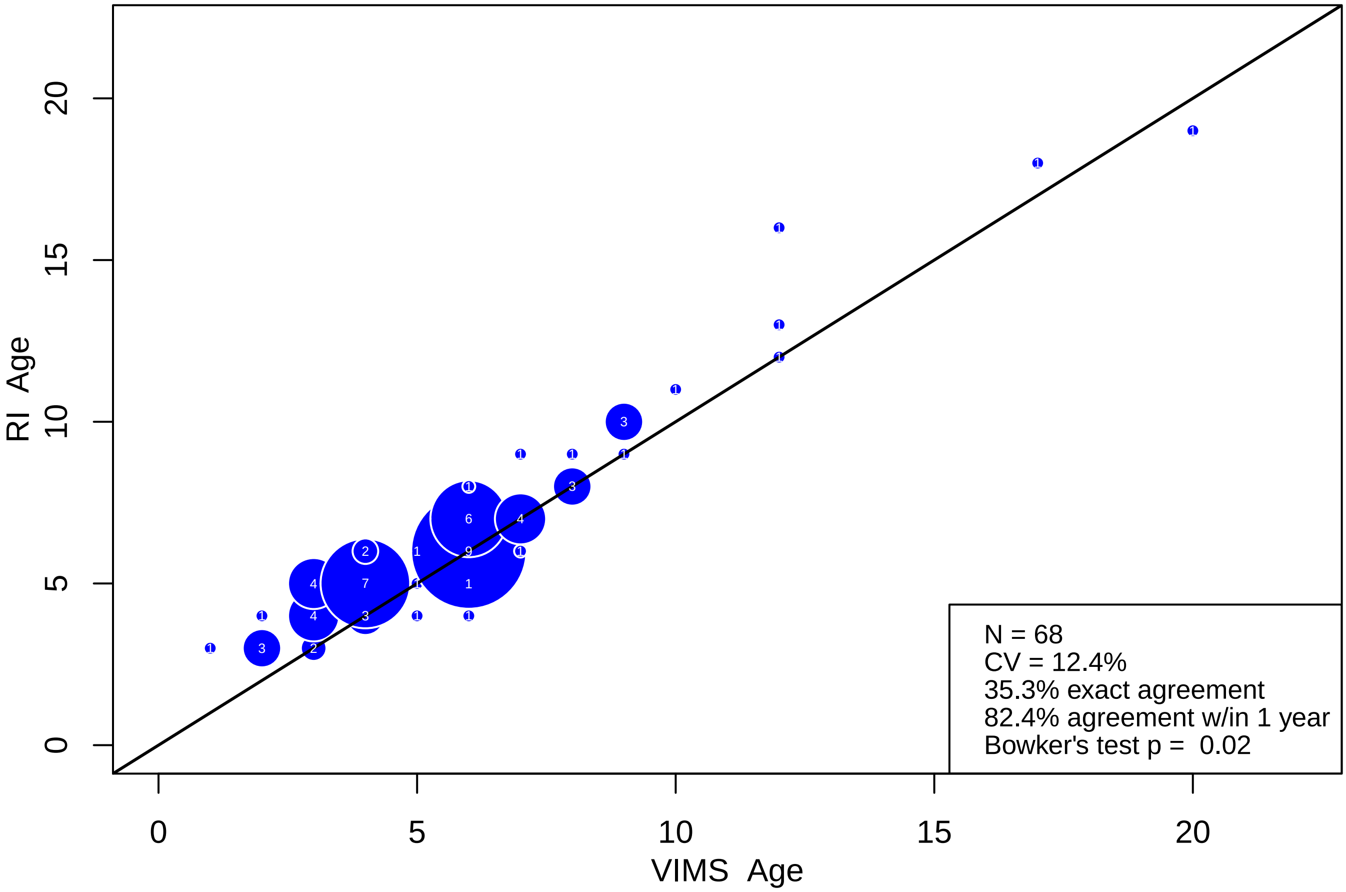


Figure 22: CT vs. VIMS bias plots by hard part. Circles are proportional to number of observations.



Operculum Ages



Otolith Ages

Figure 23: RI vs. VIMS bias plots by hard part. Circles are proportional to number of observations.

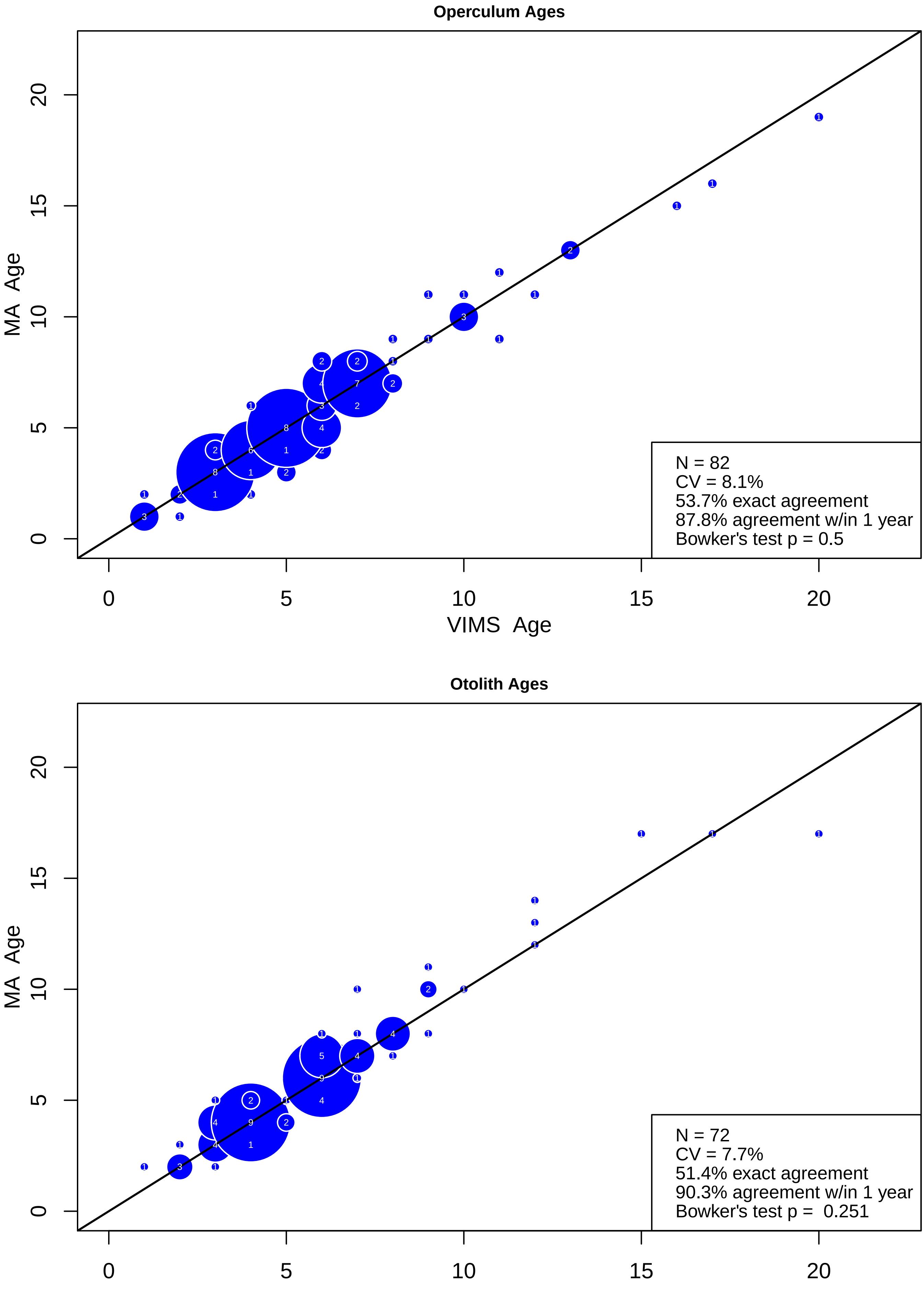


Figure 24: MA vs. VIMS bias plots by hard part. Circles are proportional to number of observations.

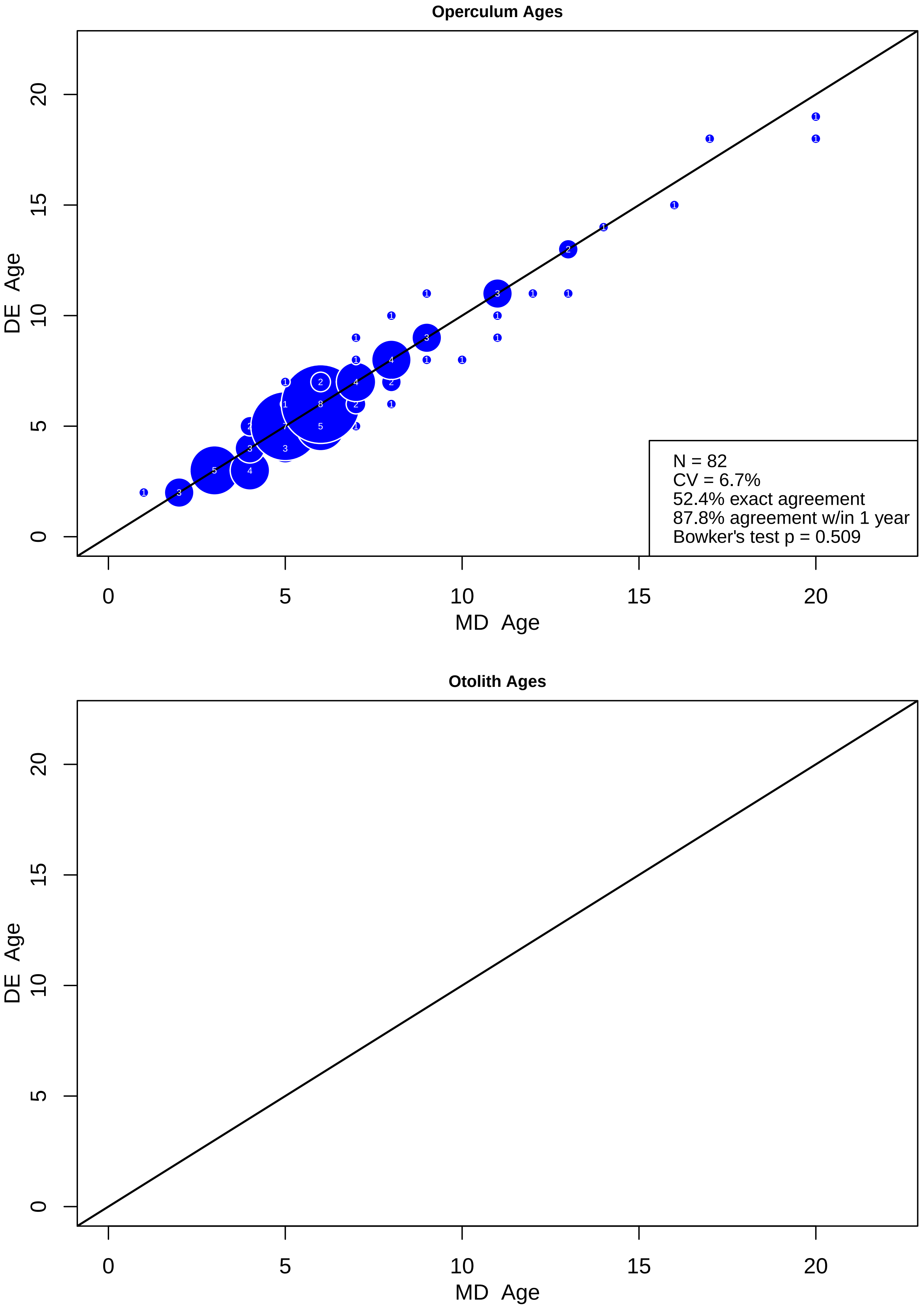


Figure 25: DE vs. MD bias plots by hard part. Circles are proportional to number of observations.

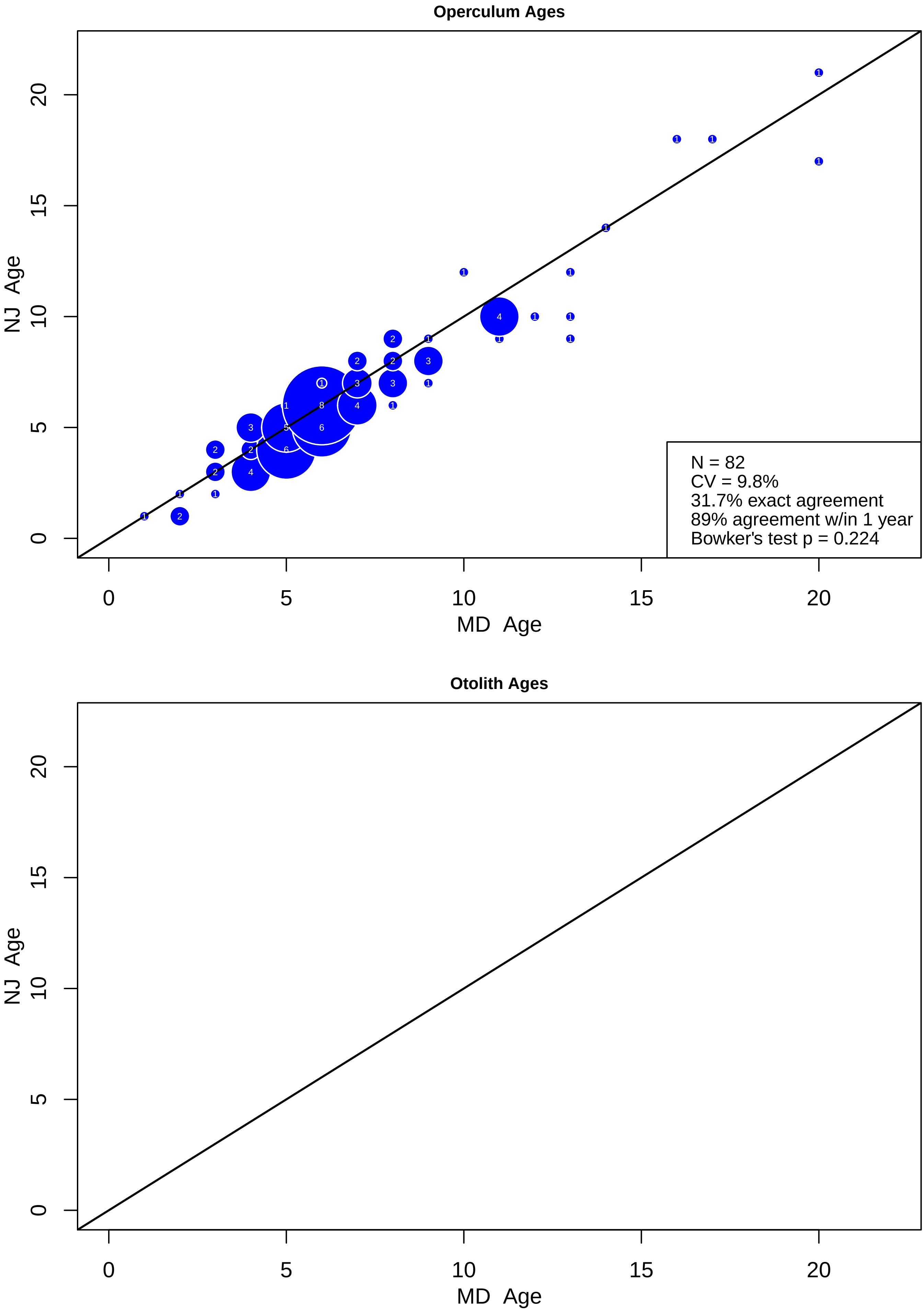


Figure 26: NJ vs. MD bias plots by hard part. Circles are proportional to number of observations.

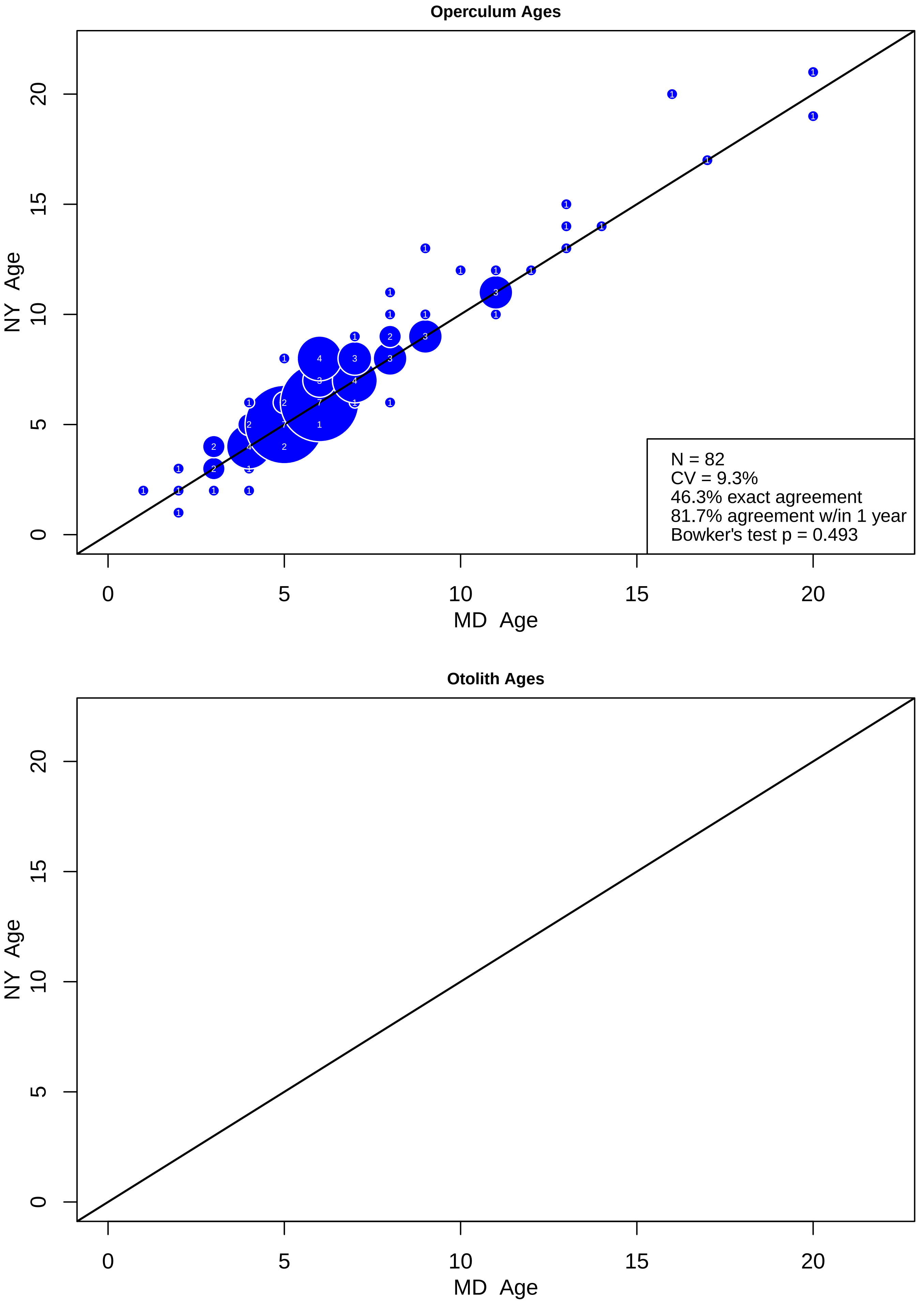


Figure 27: NY vs. MD bias plots by hard part. Circles are proportional to number of observations.

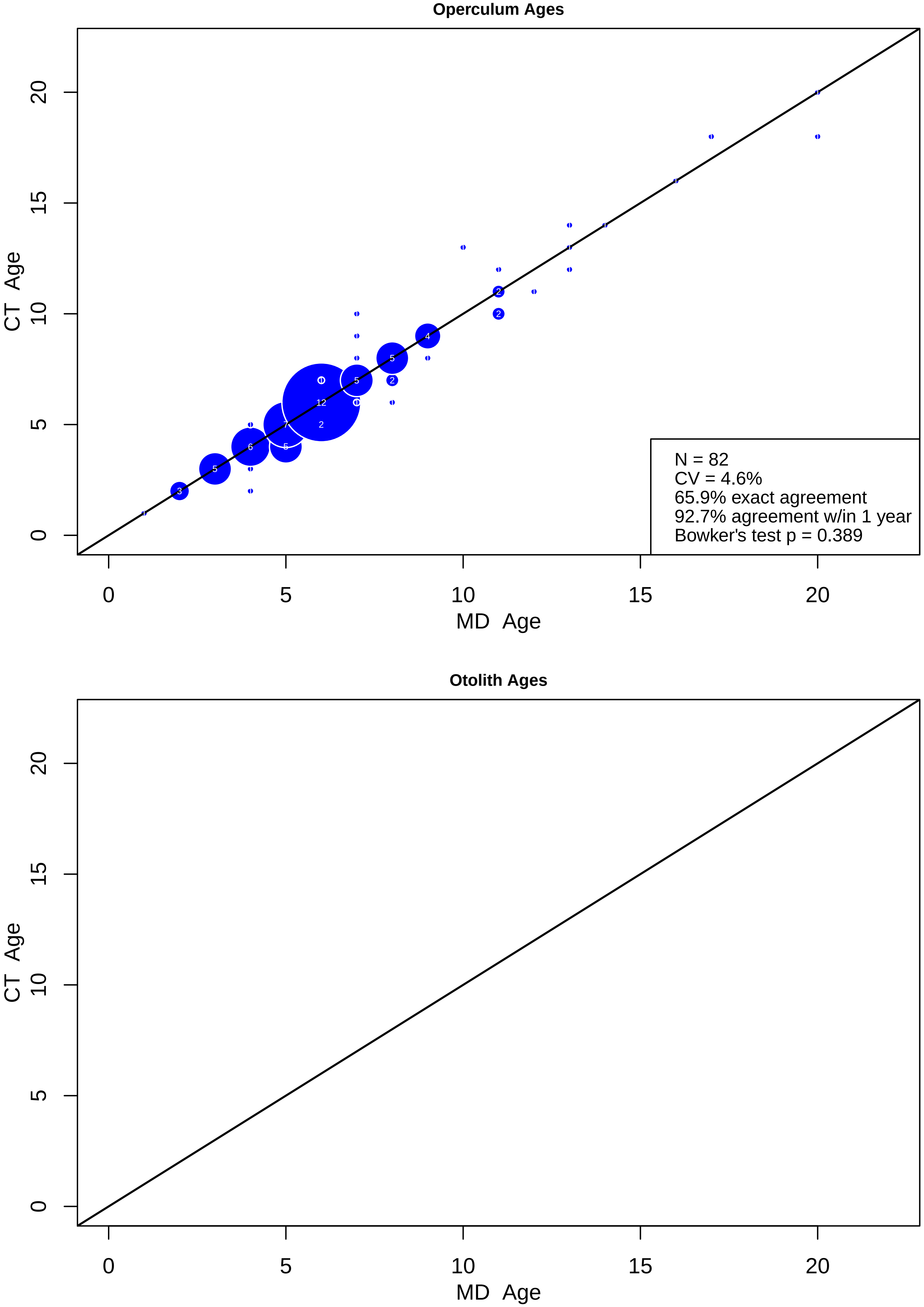


Figure 28: CT vs. MD bias plots by hard part. Circles are proportional to number of observations.

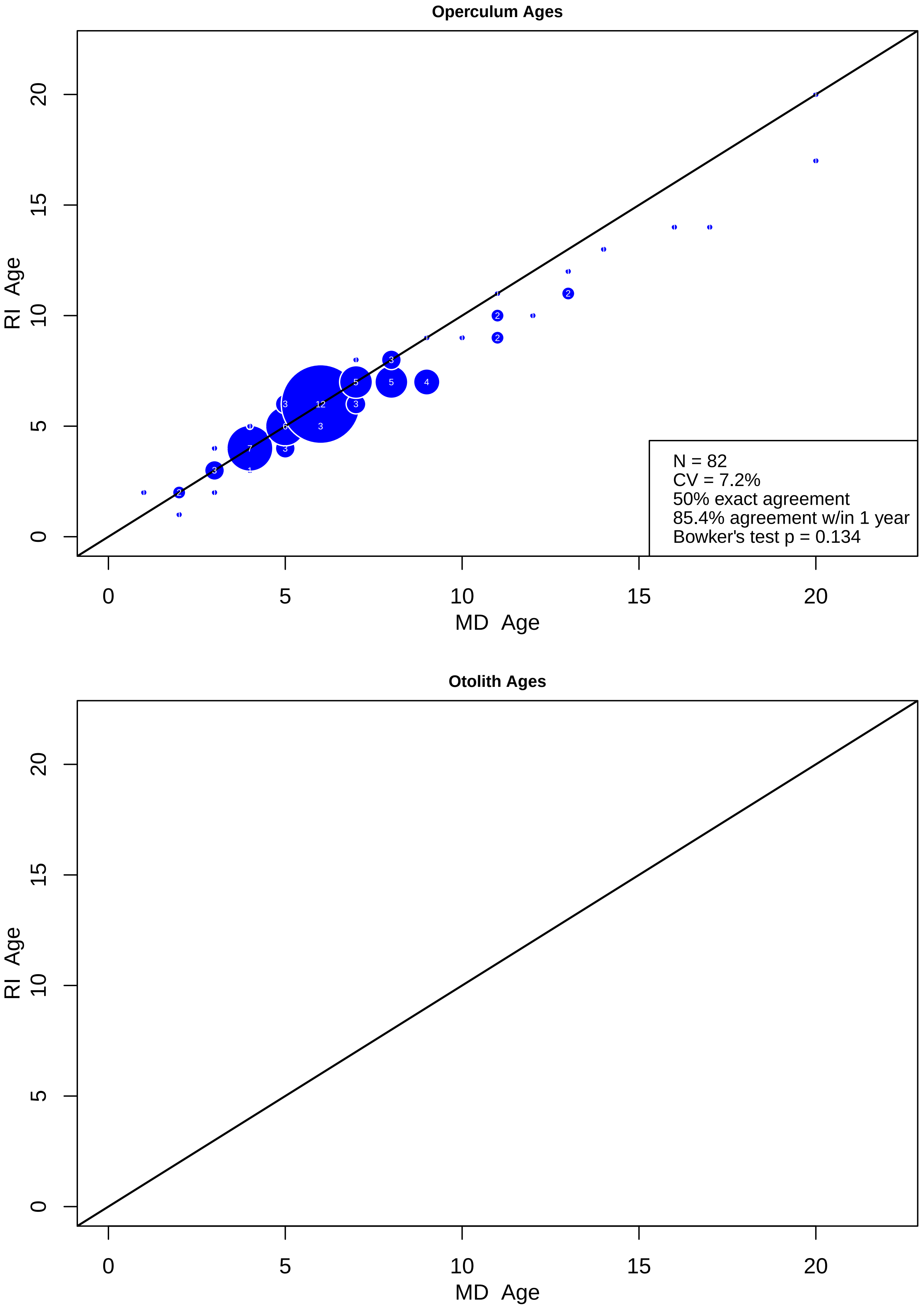


Figure 29: RI vs. MD bias plots by hard part. Circles are proportional to number of observations.

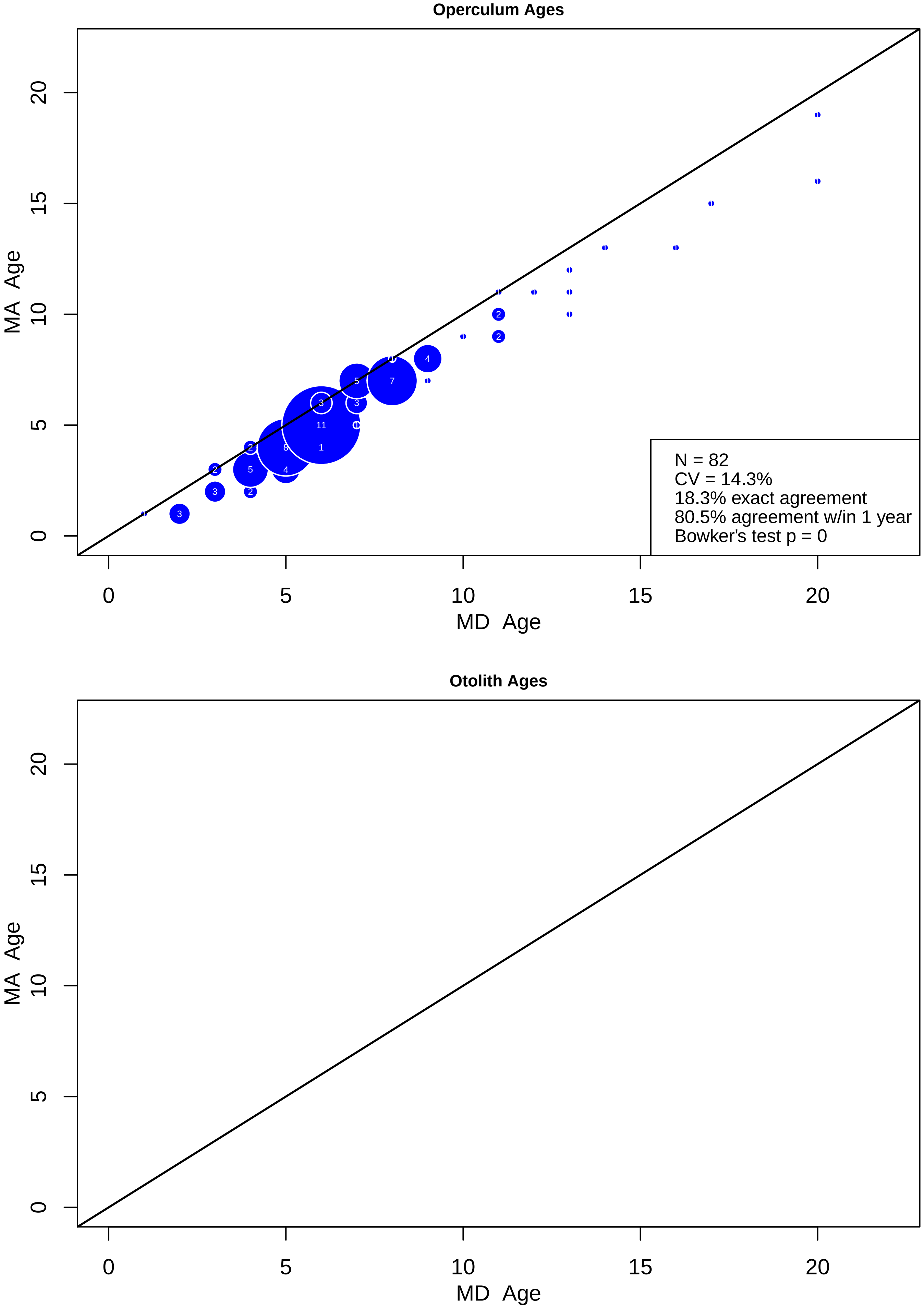


Figure 30: MA vs. MD bias plots by hard part. Circles are proportional to number of observations.

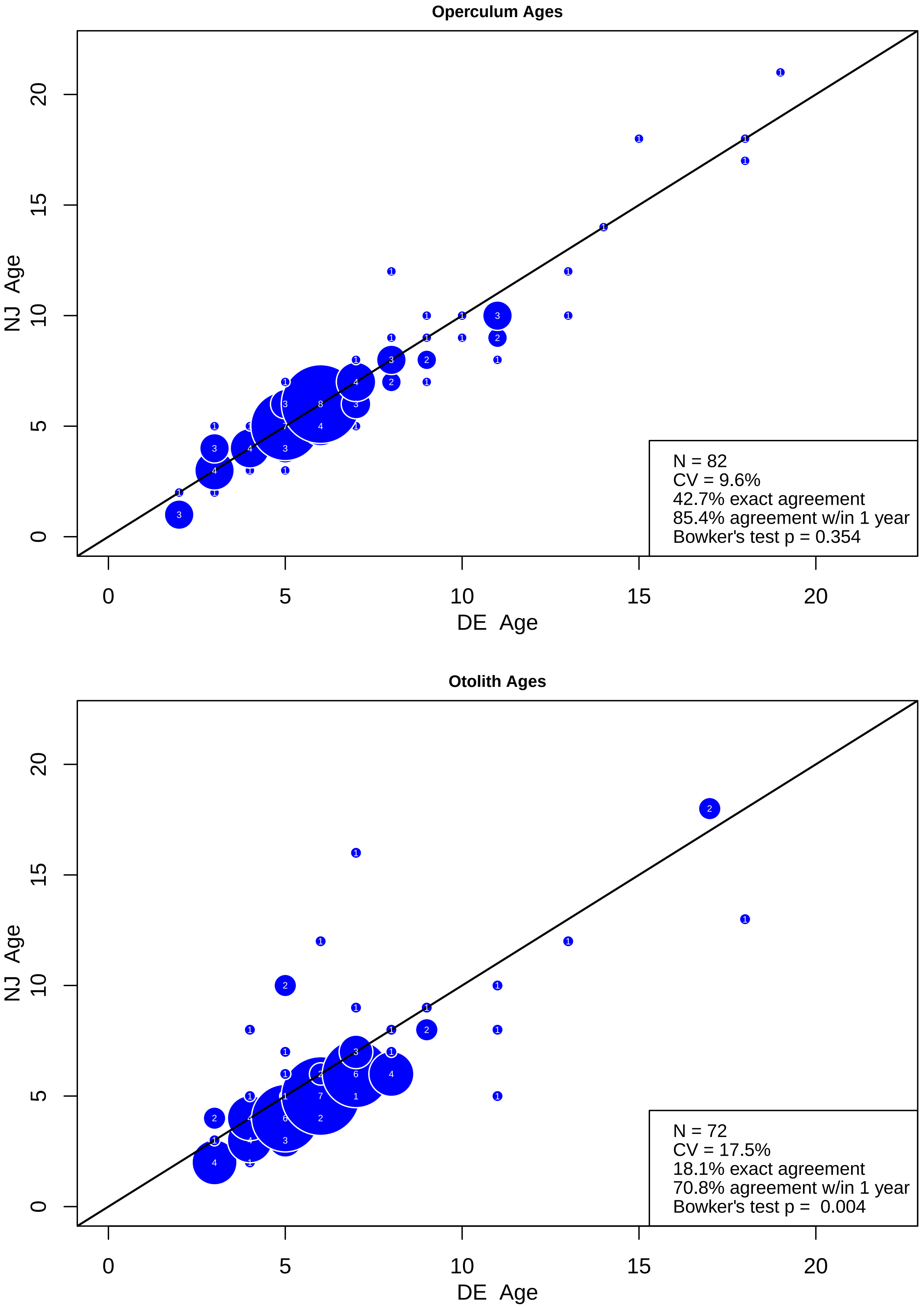
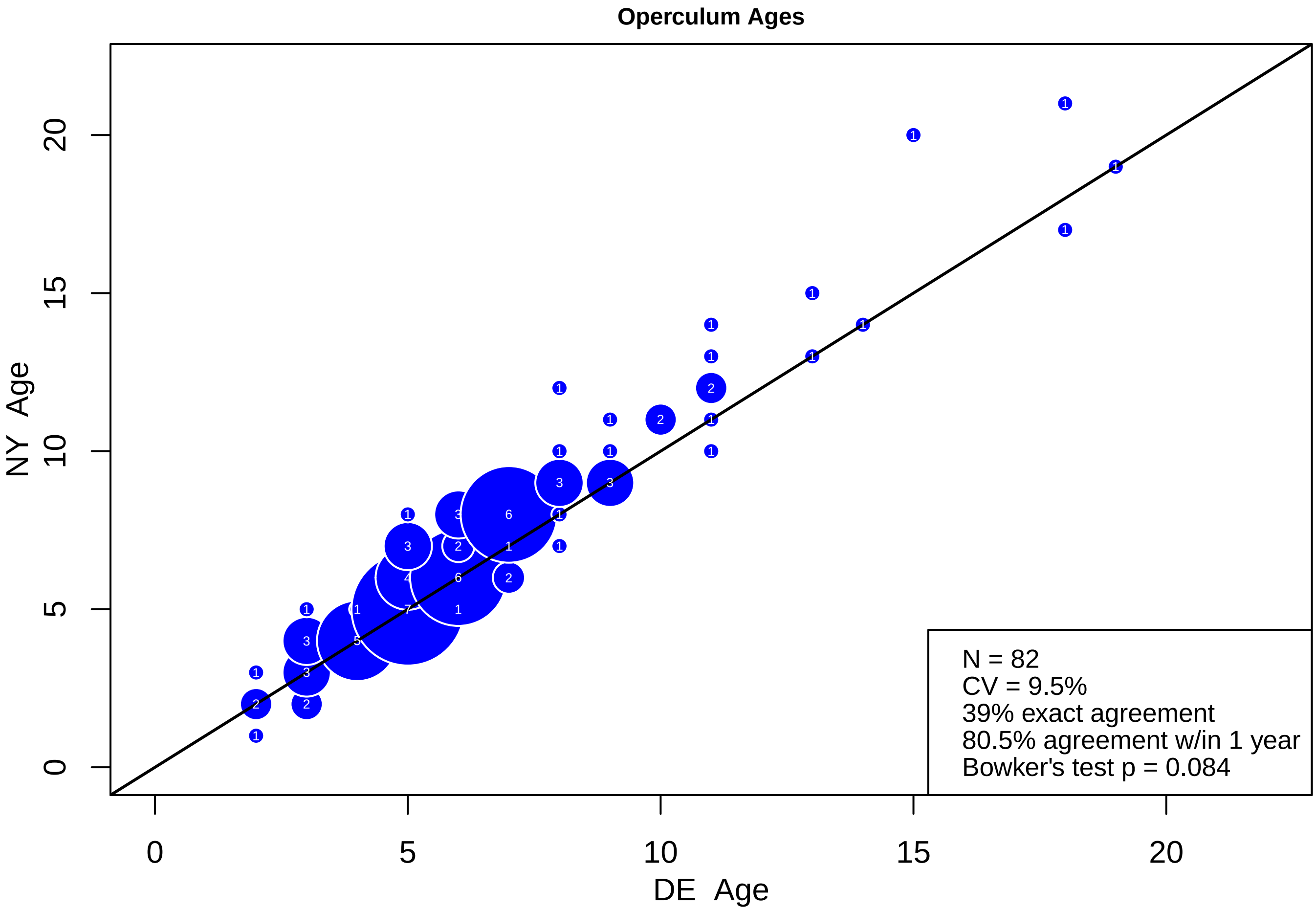


Figure 31: NJ vs. DE bias plots by hard part. Circles are proportional to number of observations.


Operculum Ages

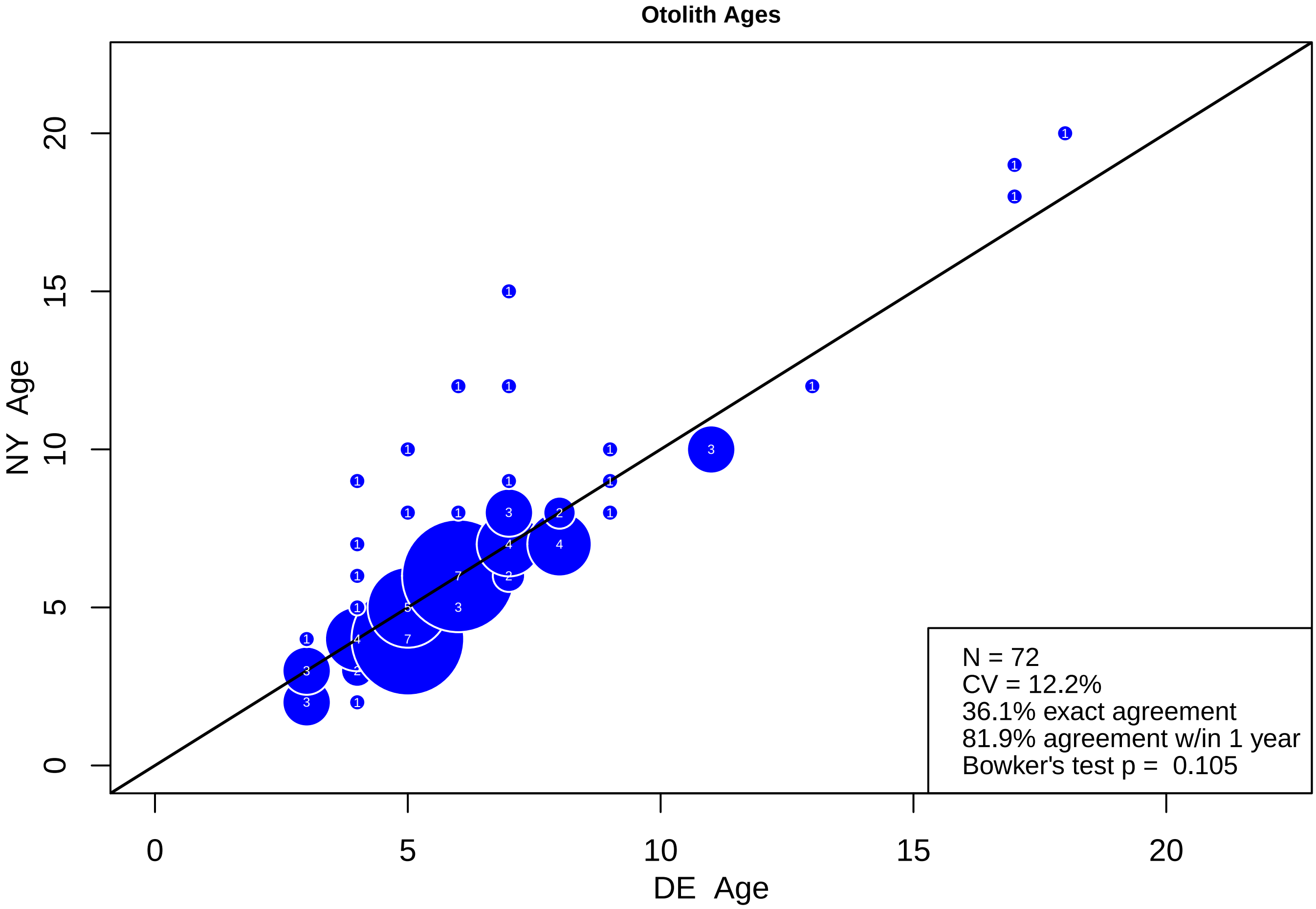

Otolith Ages

Figure 32: NY vs. DE bias plots by hard part. Circles are proportional to number of observations.

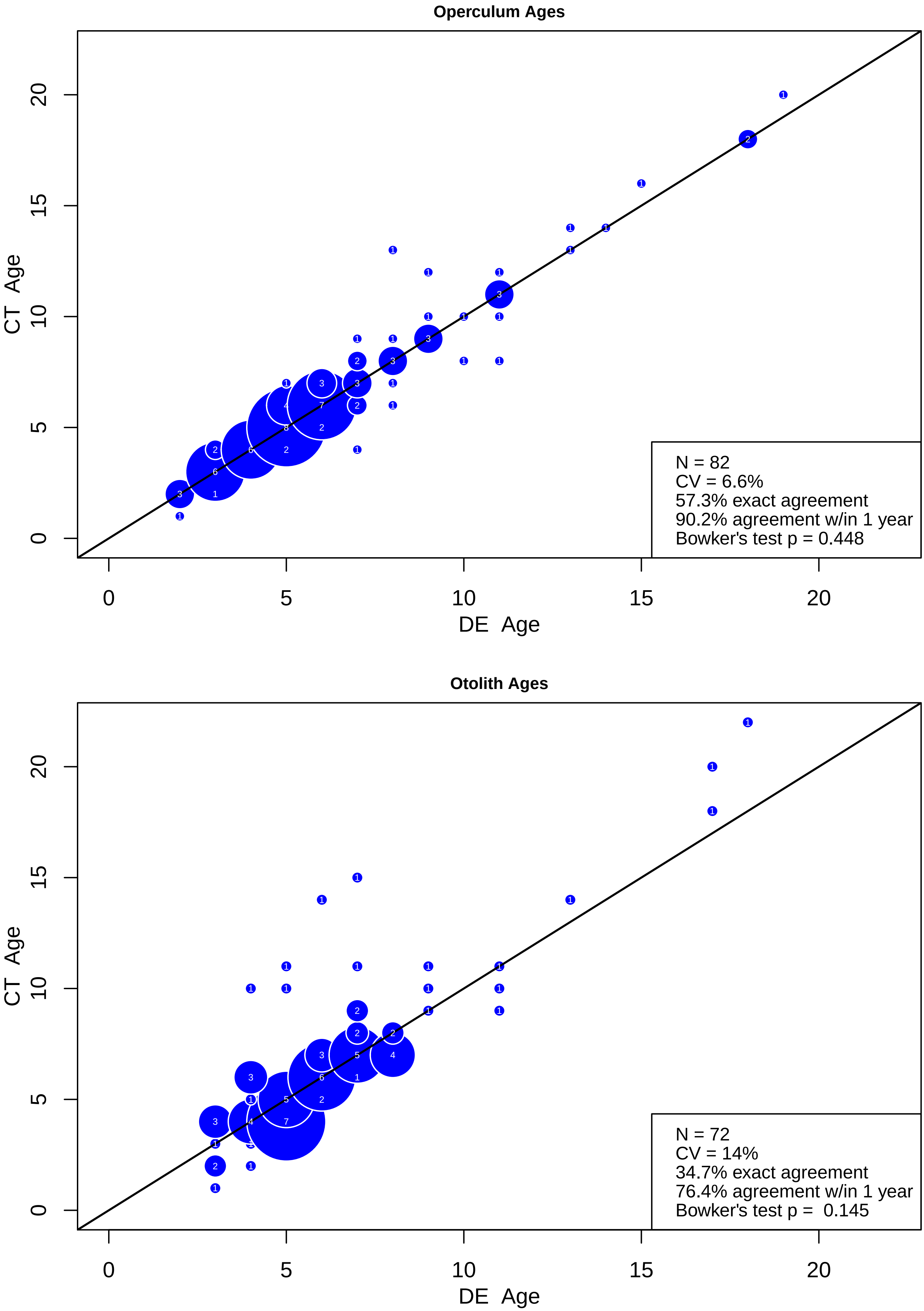


Figure 33: CT vs. DE bias plots by hard part. Circles are proportional to number of observations.

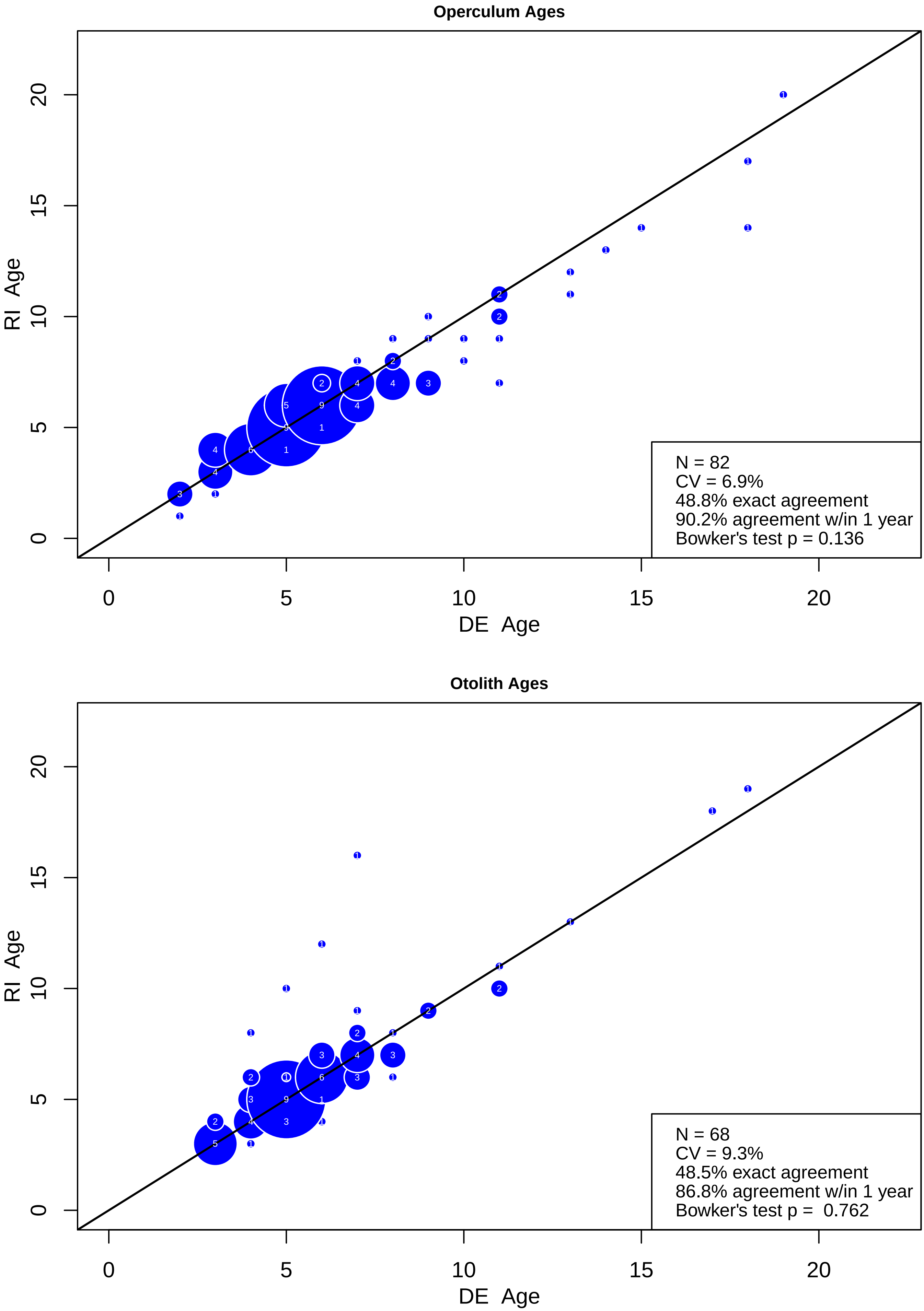


Figure 34: RI vs. DE bias plots by hard part. Circles are proportional to number of observations.

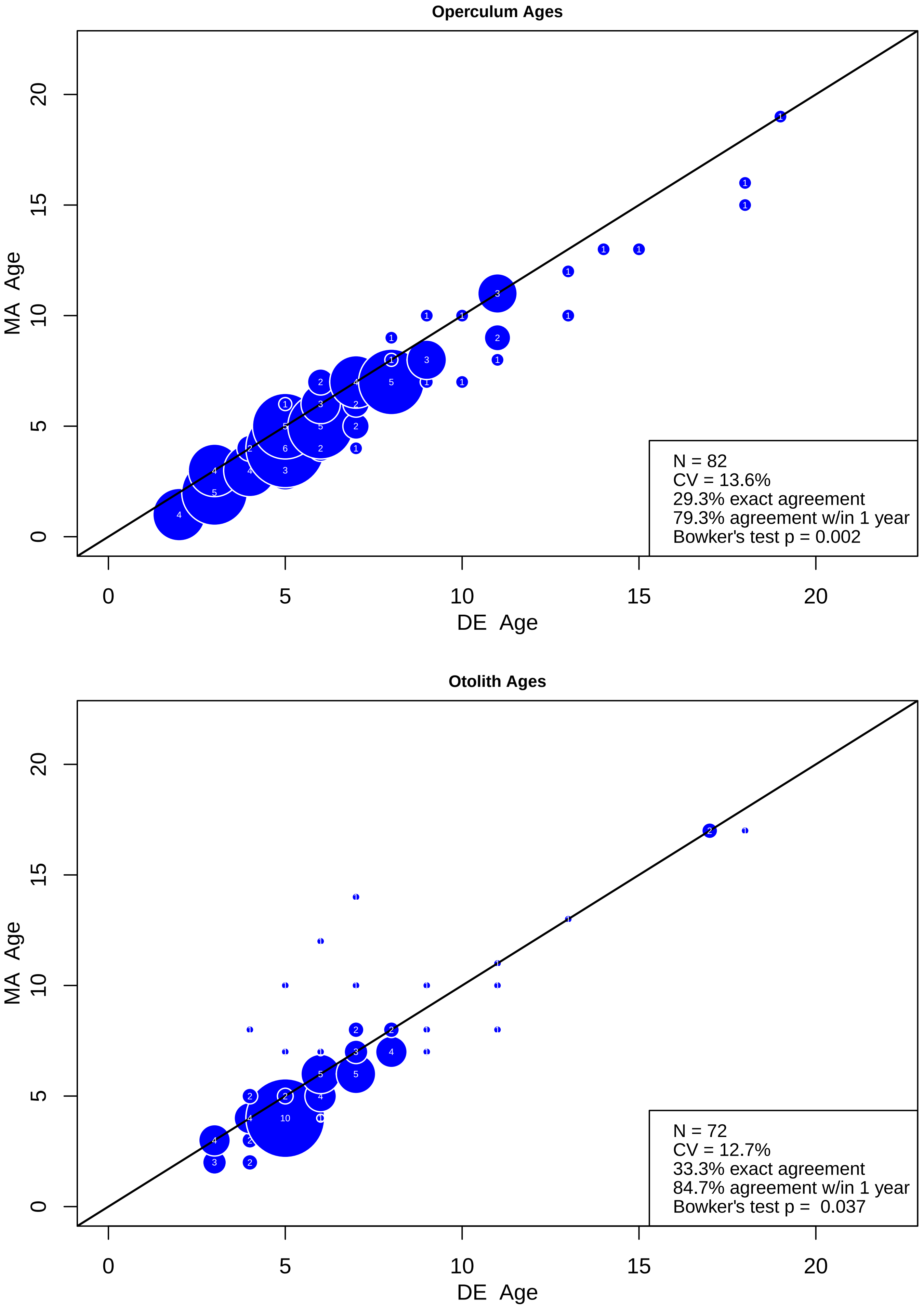
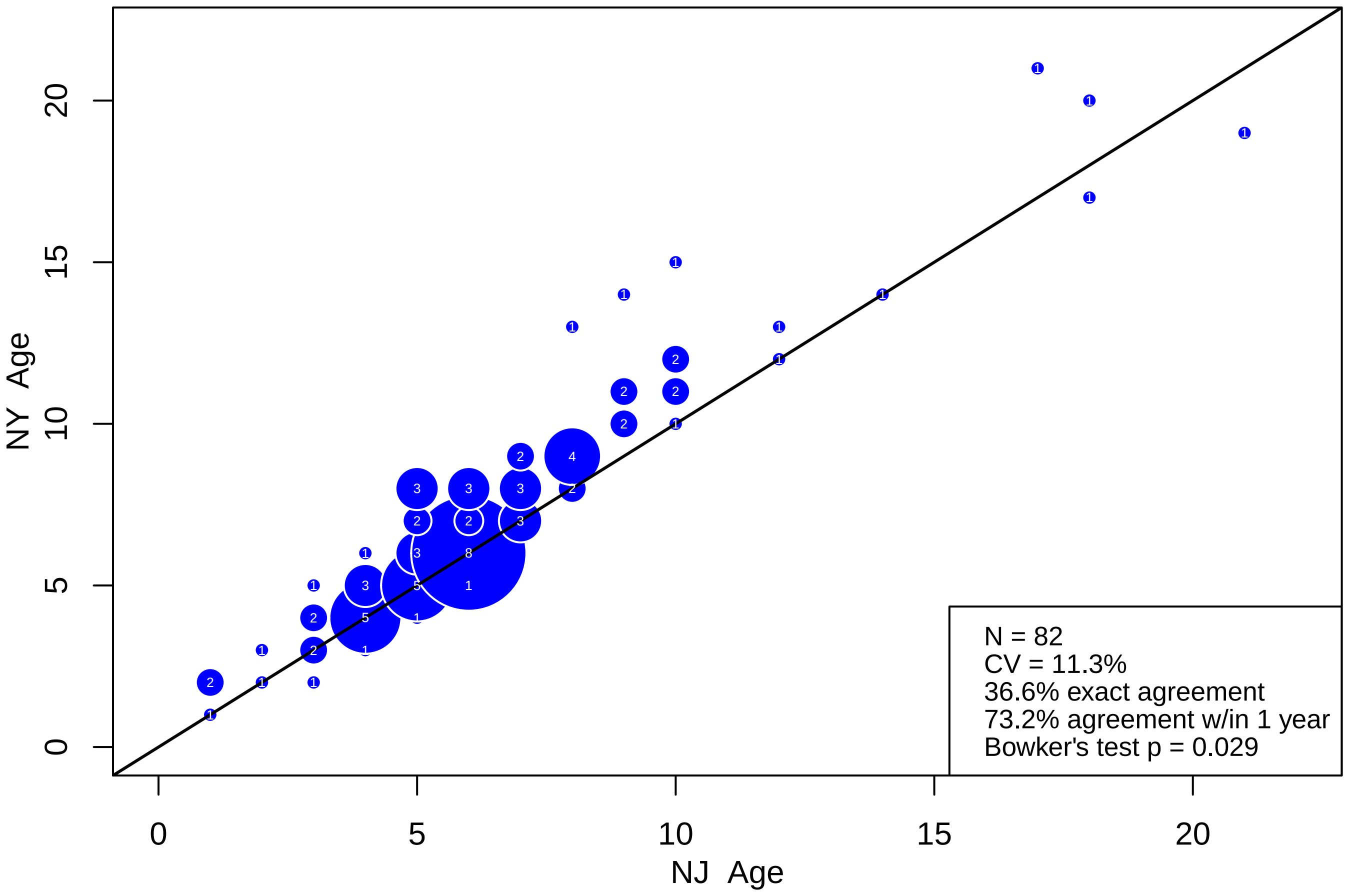


Figure 35: MA vs. DE bias plots by hard part. Circles are proportional to number of observations.

Operculum Ages



Otolith Ages

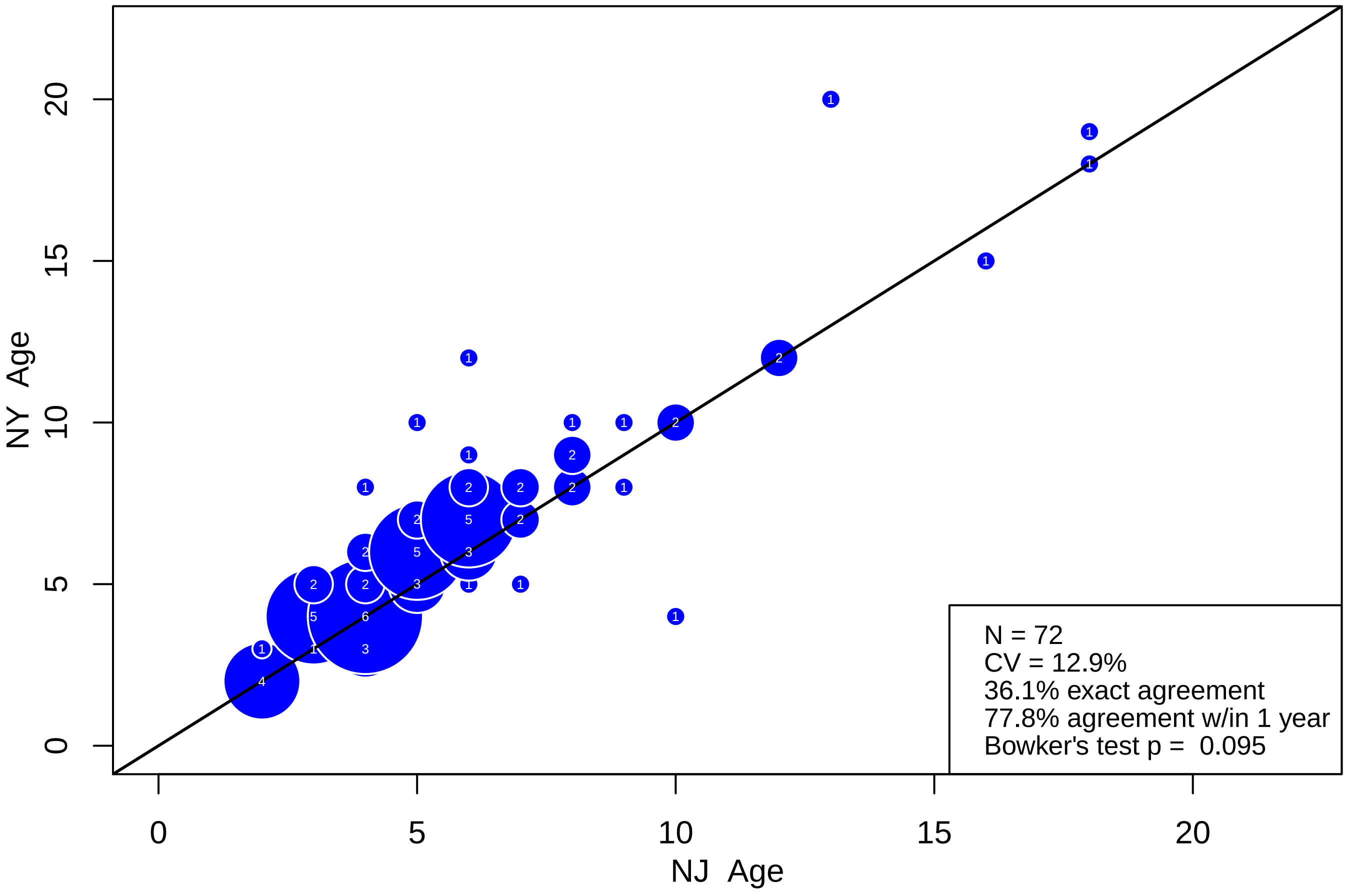
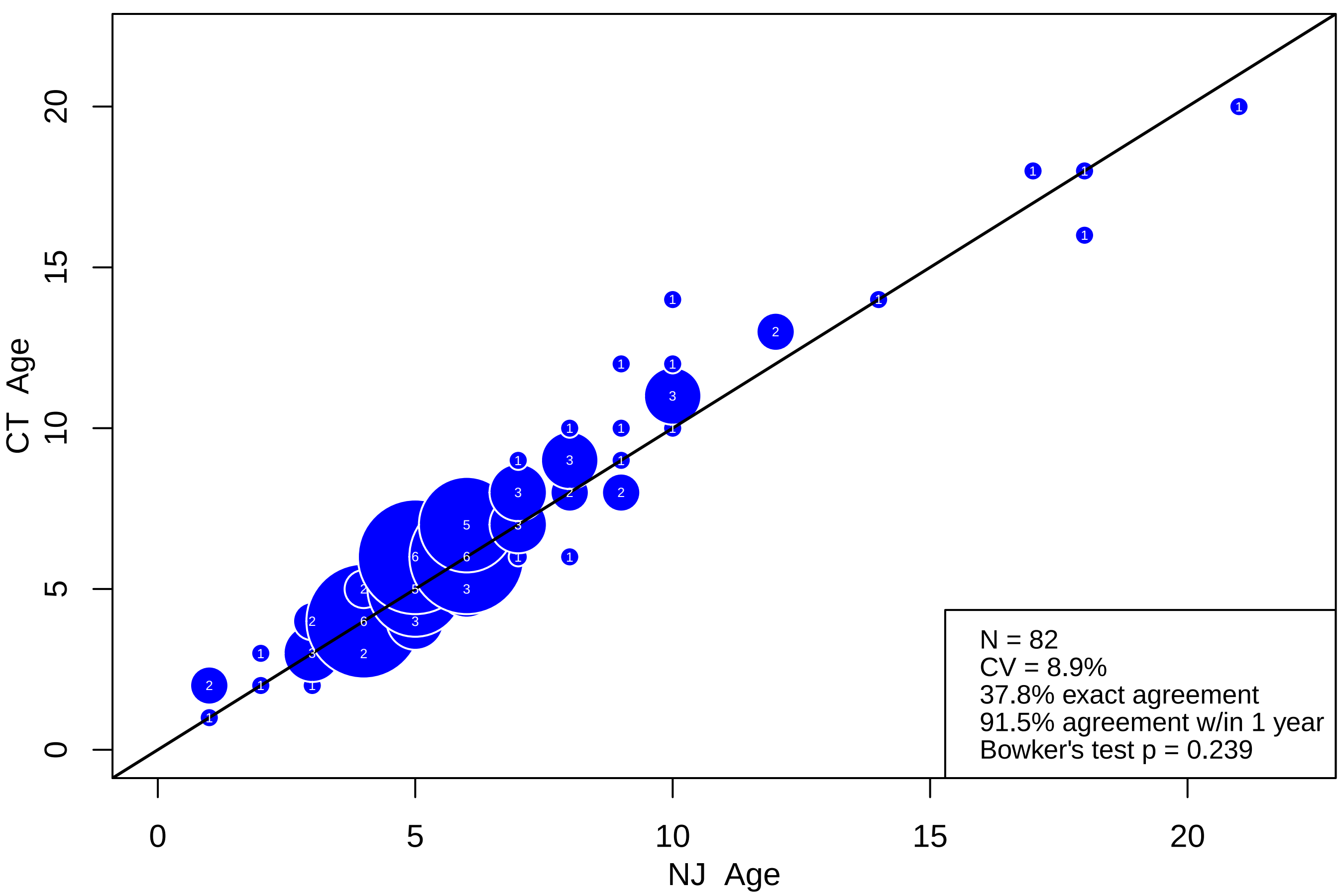
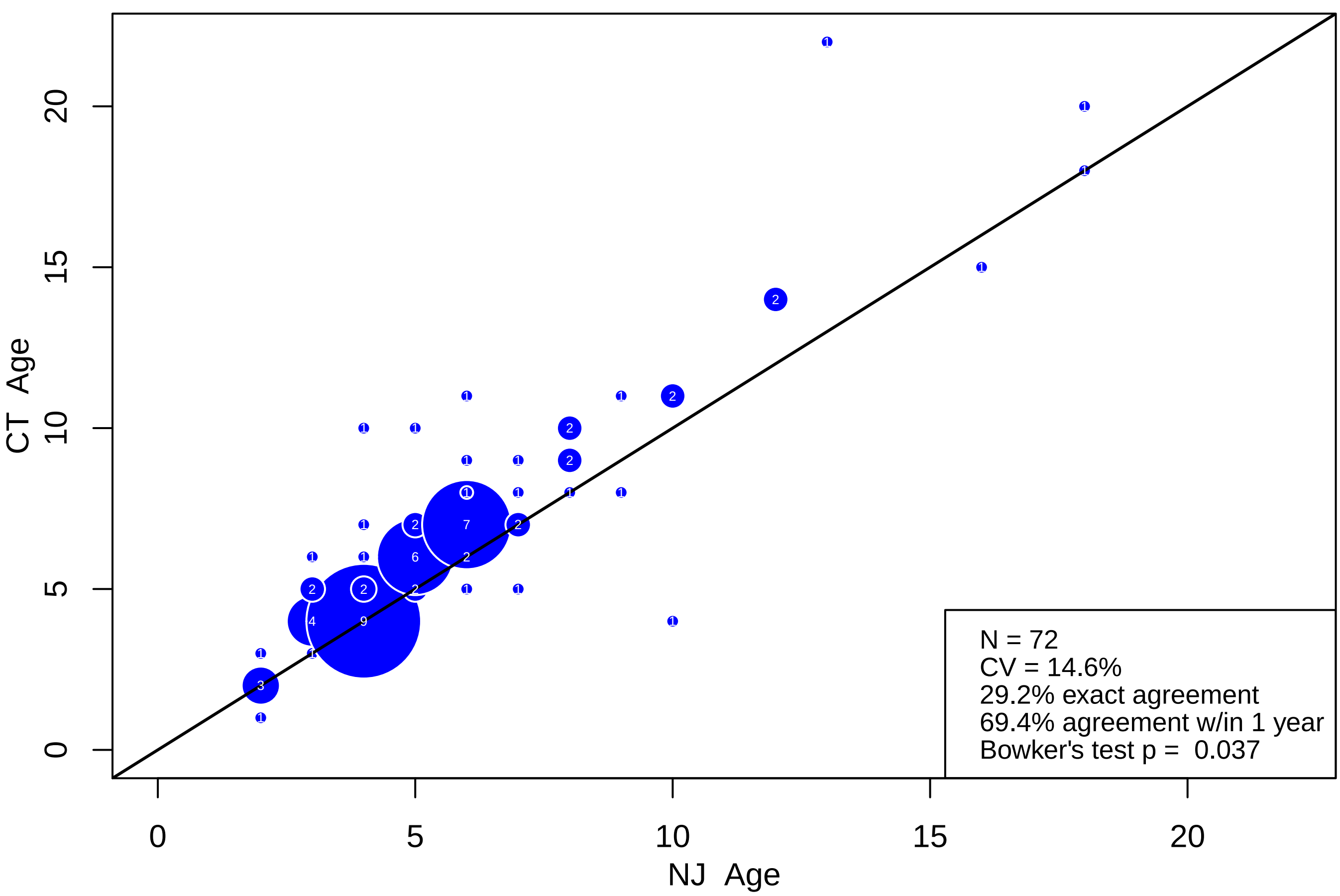


Figure 36: NY vs. NJ bias plots by hard part. Circles are proportional to number of observations.



Operculum Ages



Otolith Ages

Figure 37: CT vs. NJ bias plots by hard part. Circles are proportional to number of observations.

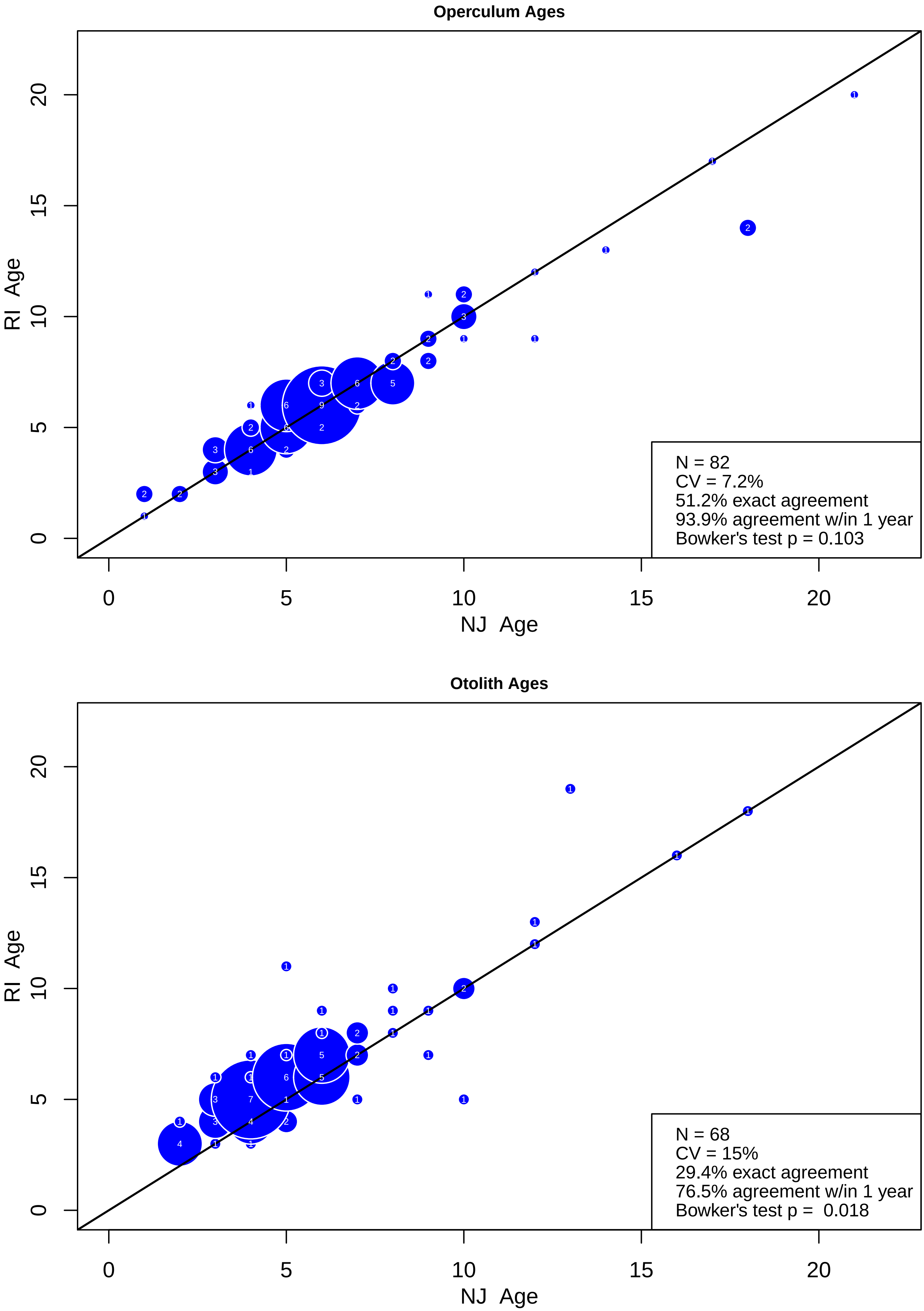


Figure 38: RI vs. NJ bias plots by hard part. Circles are proportional to number of observations.

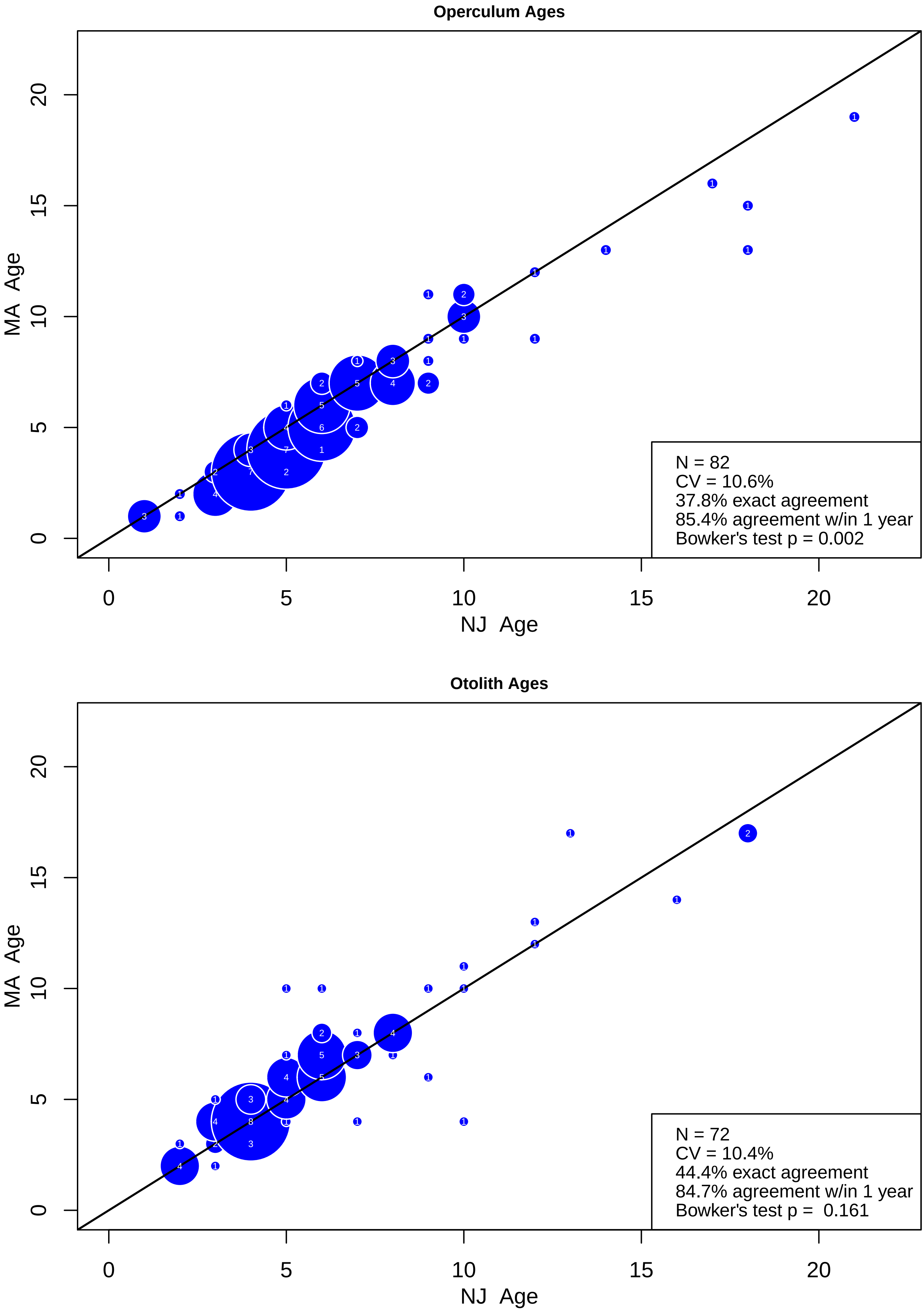
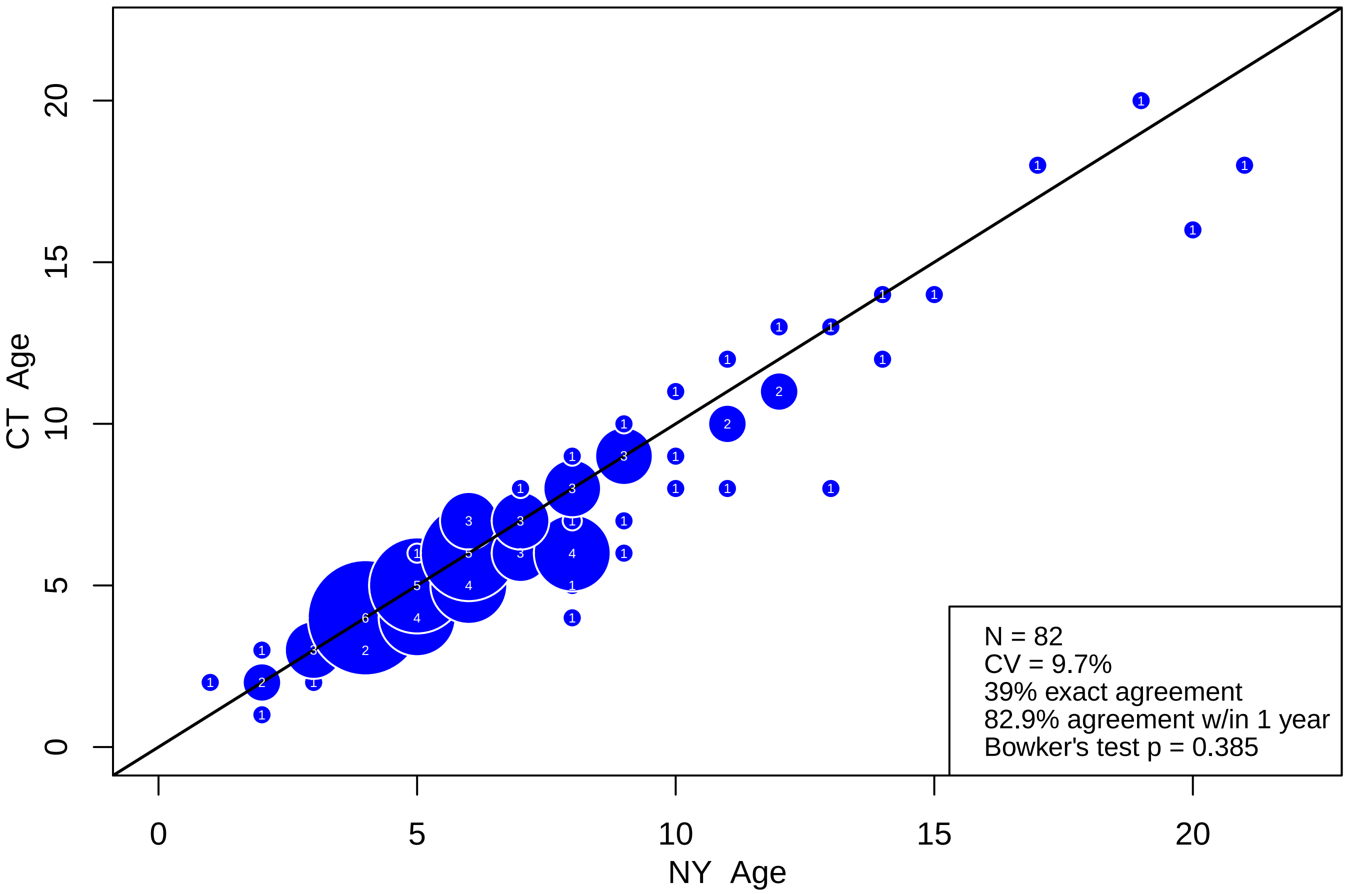


Figure 39: MA vs. NJ bias plots by hard part. Circles are proportional to number of observations.

Operculum Ages



Otolith Ages

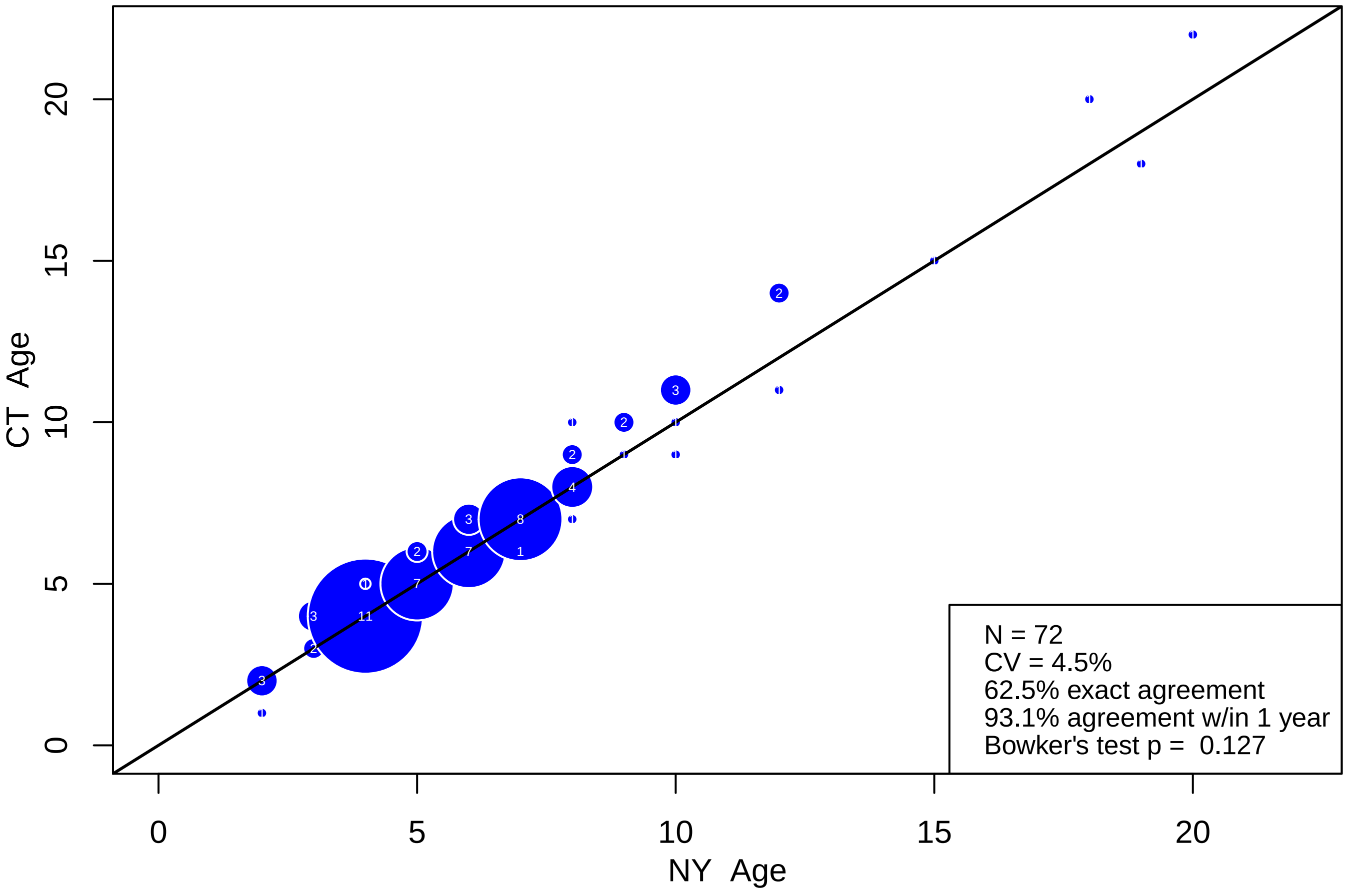


Figure 40: CT vs. NY bias plots by hard part. Circles are proportional to number of observations.

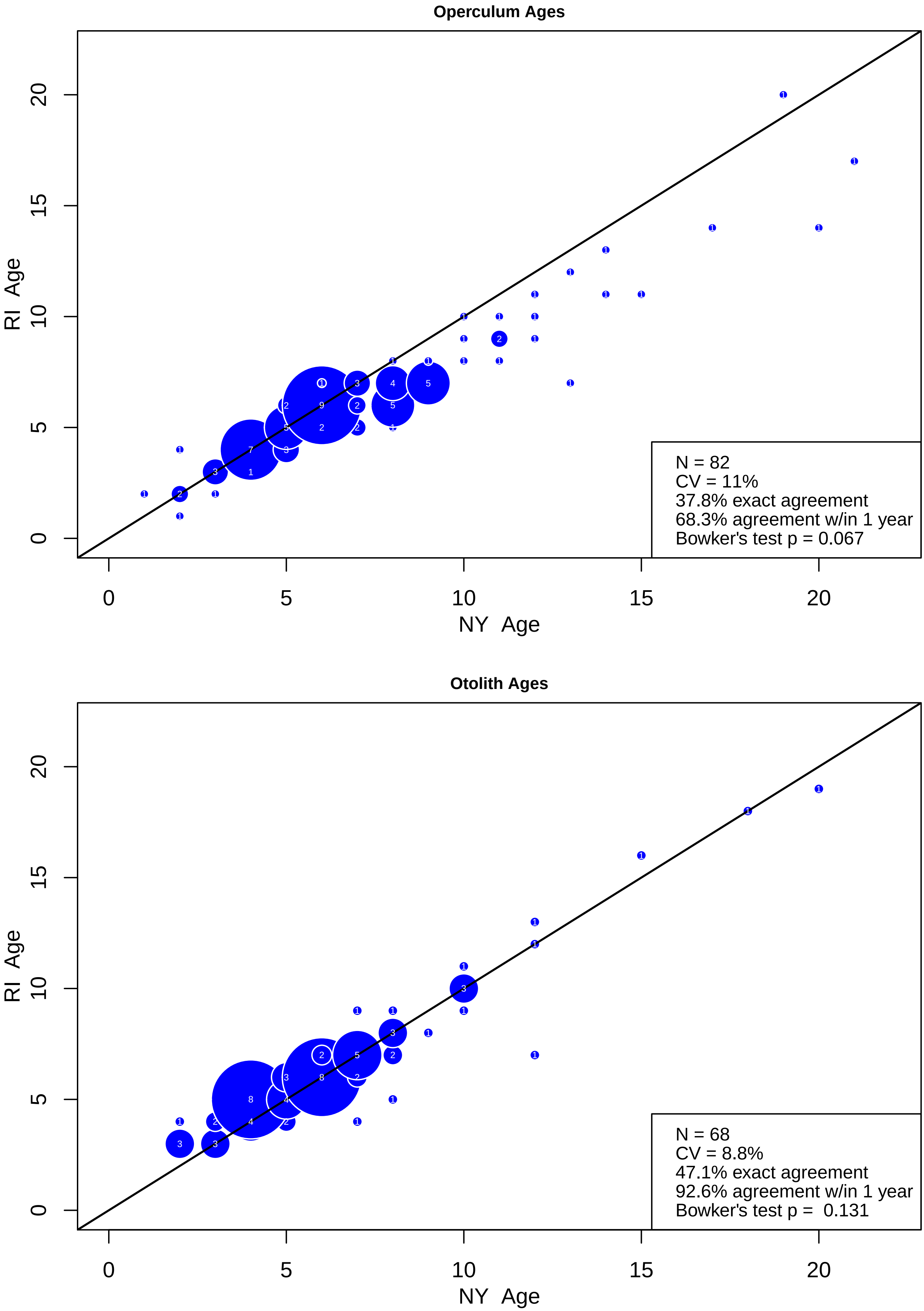
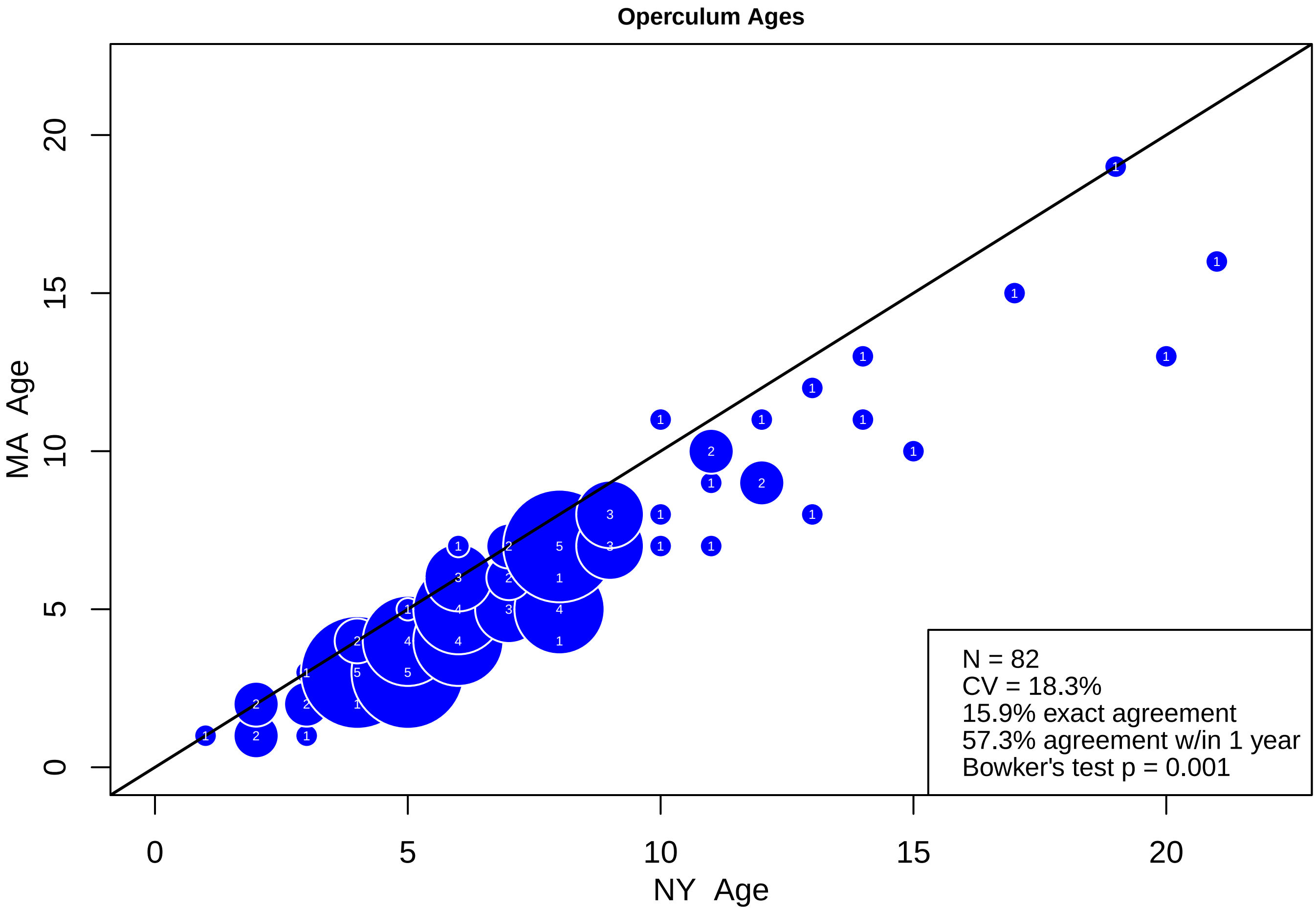
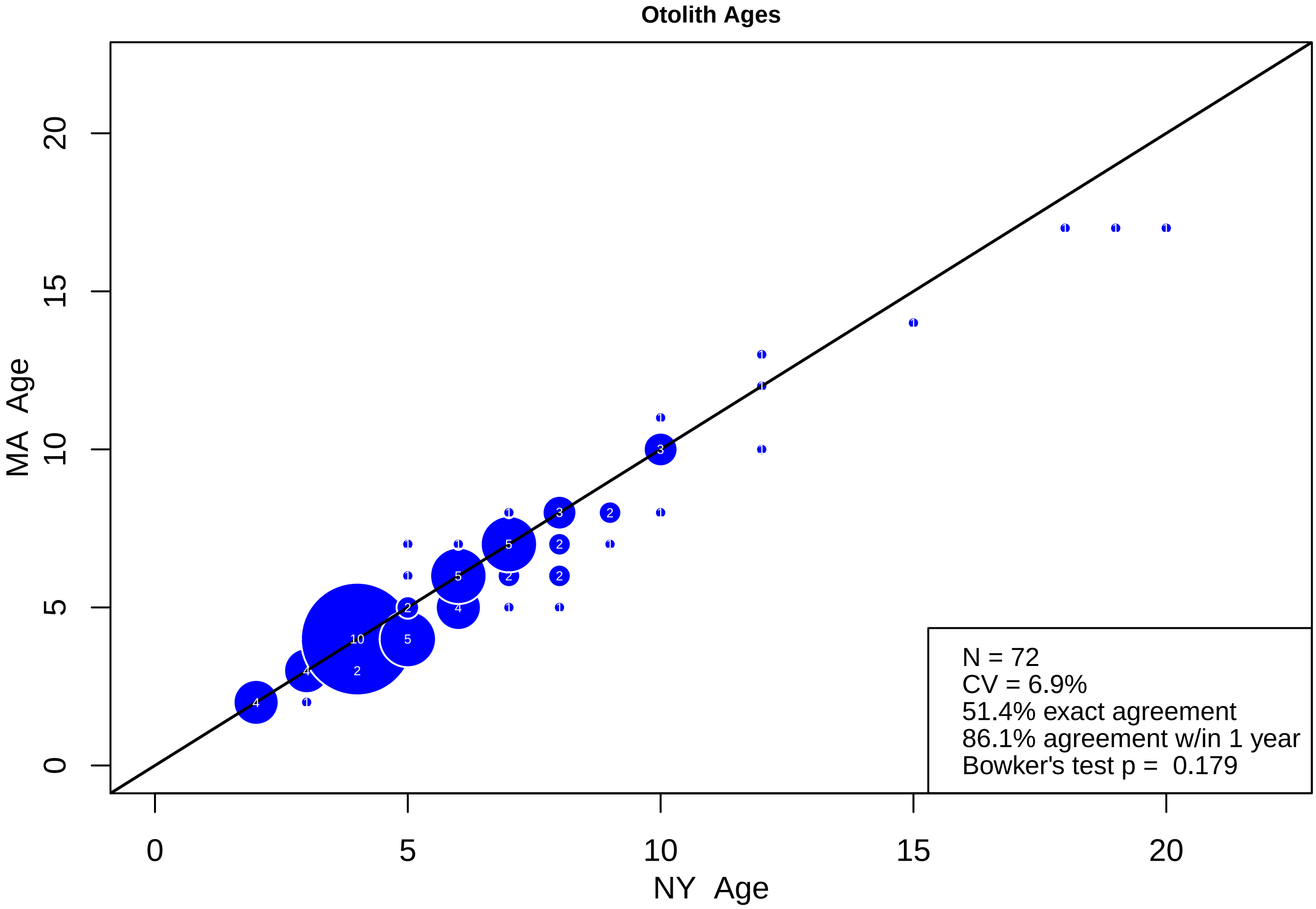


Figure 41: RI vs. NY bias plots by hard part. Circles are proportional to number of observations.

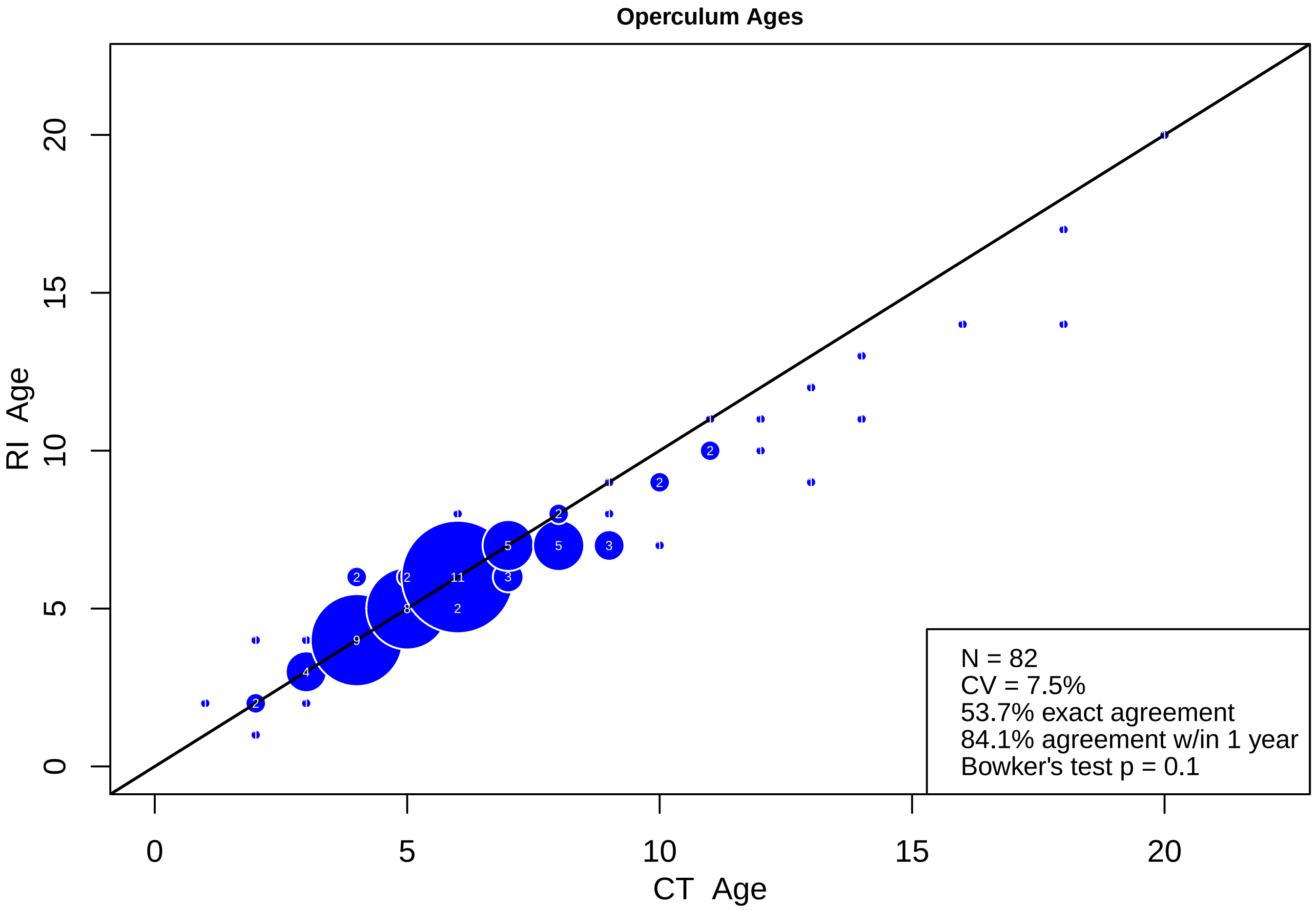


Operculum Ages



Otolith Ages

Figure 42: MA vs. NY bias plots by hard part. Circles are proportional to number of observations.



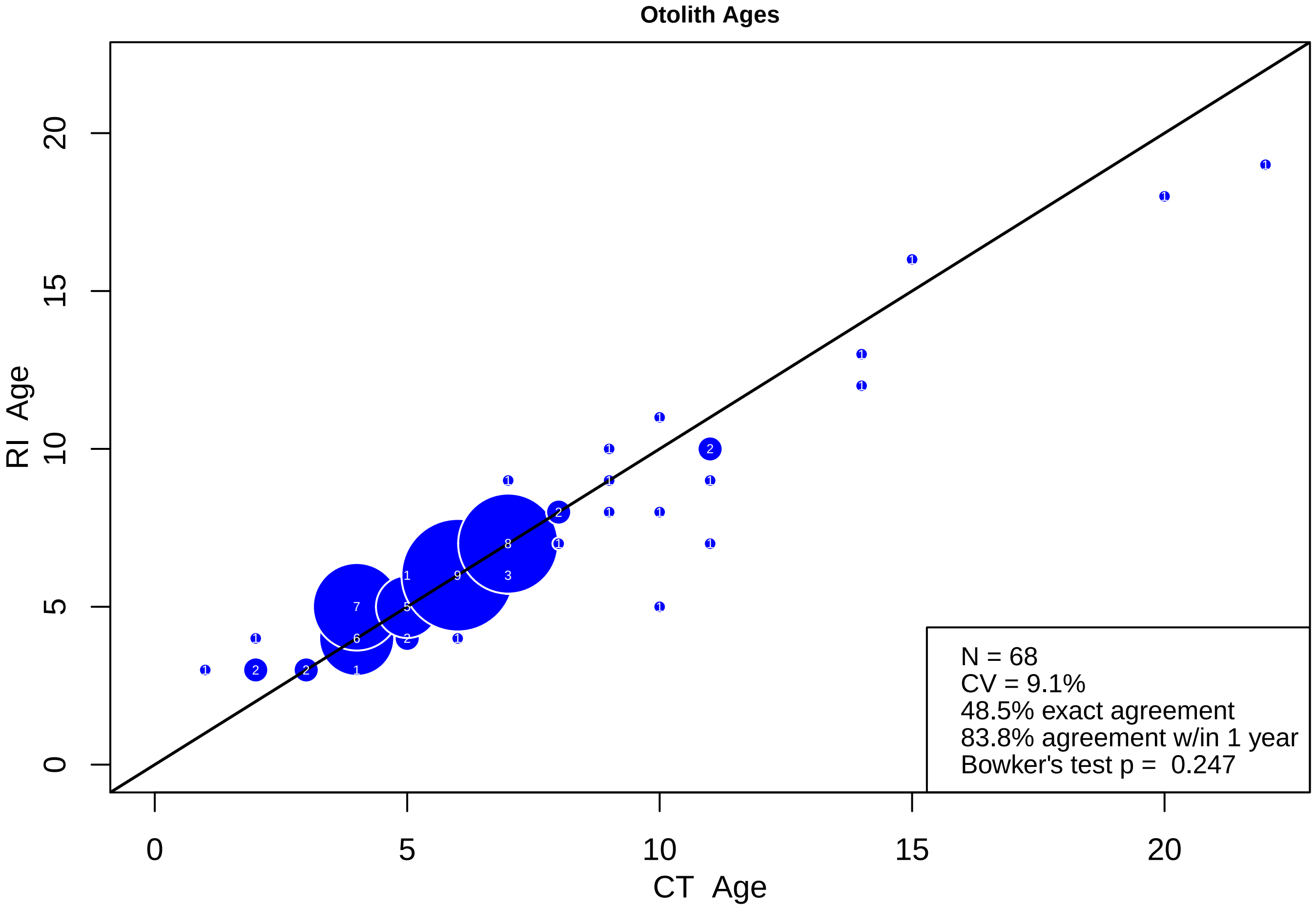


Figure 43: RI vs. CT bias plots by hard part. Circles are proportional to number of observations.

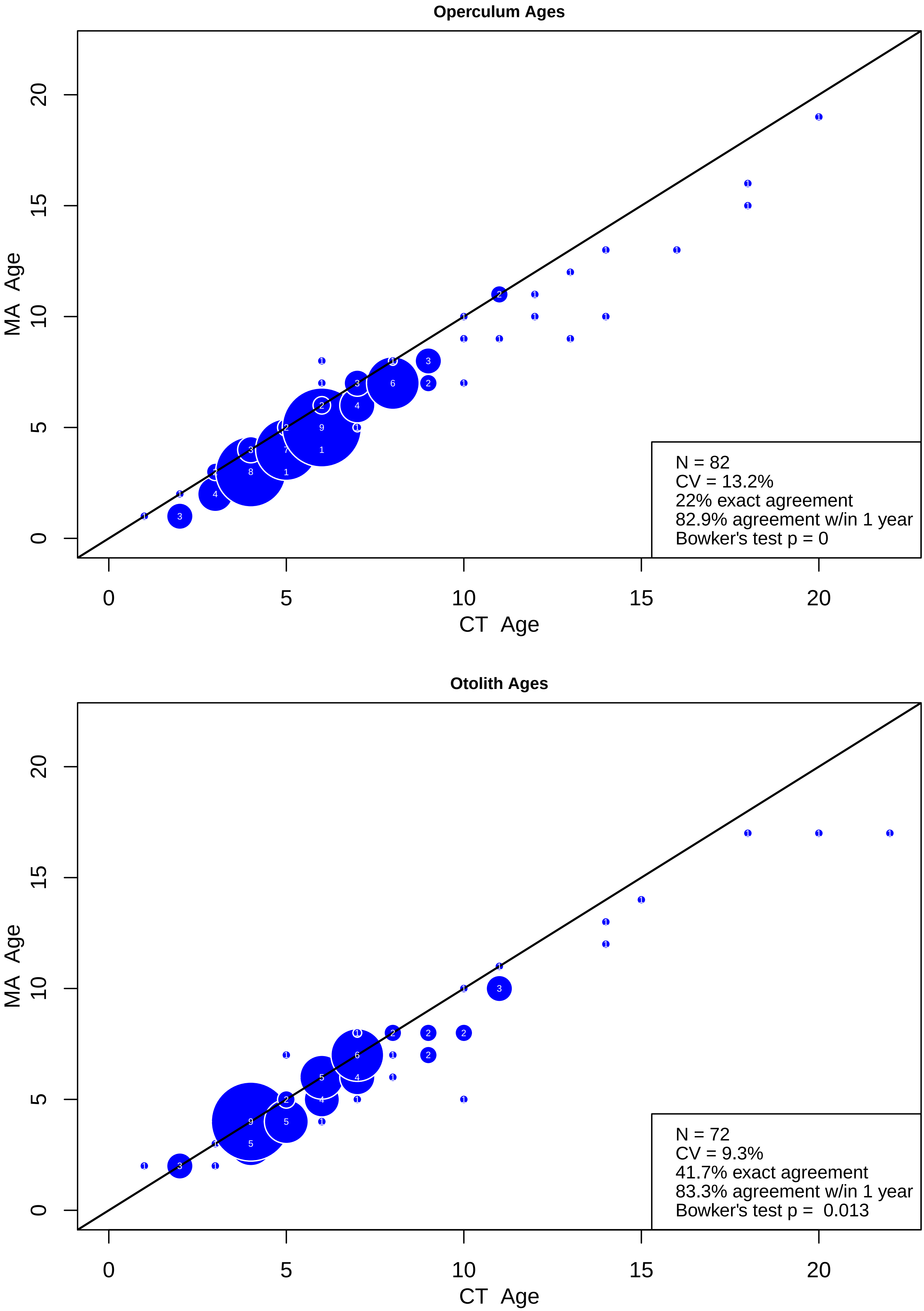
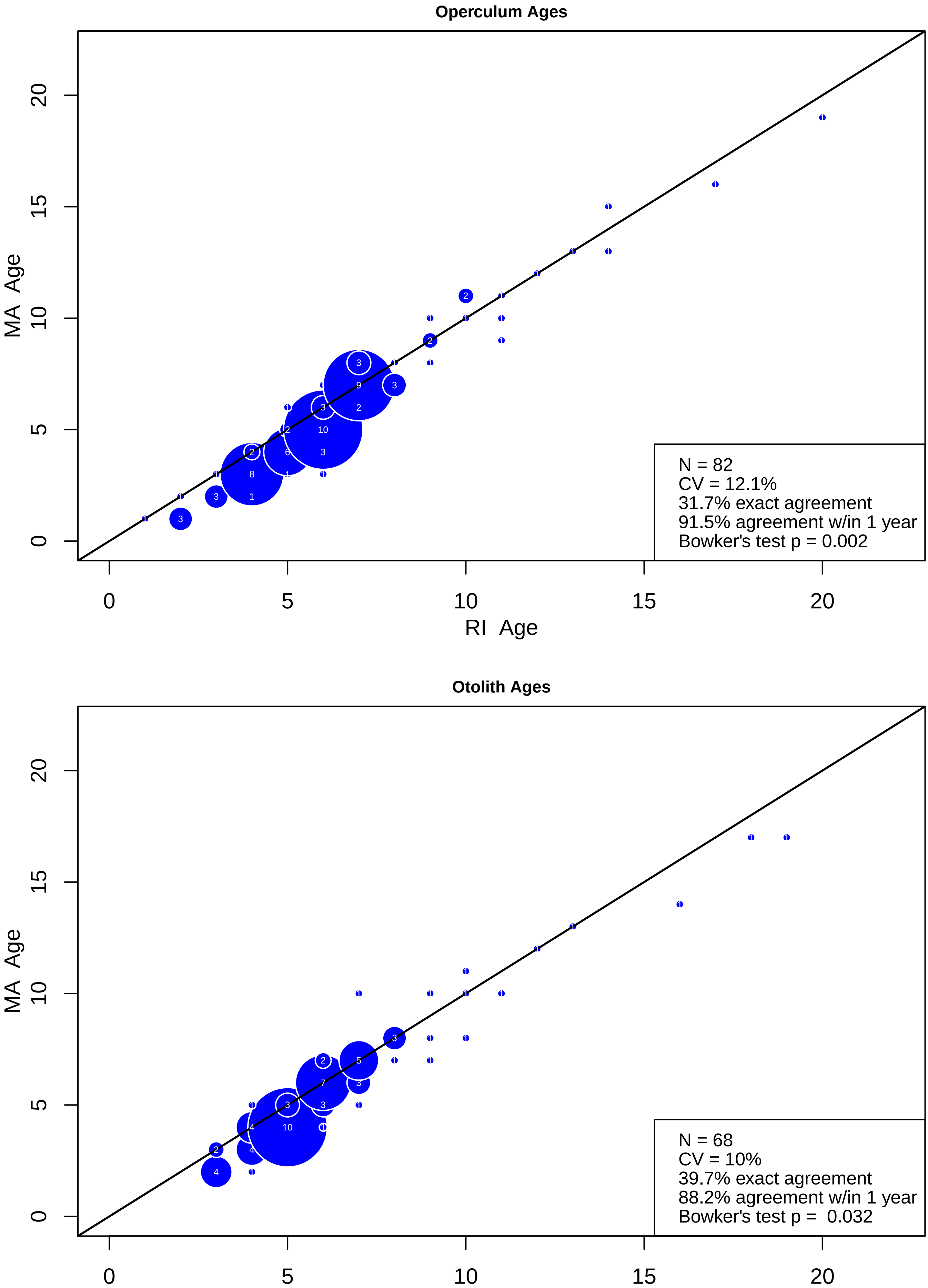


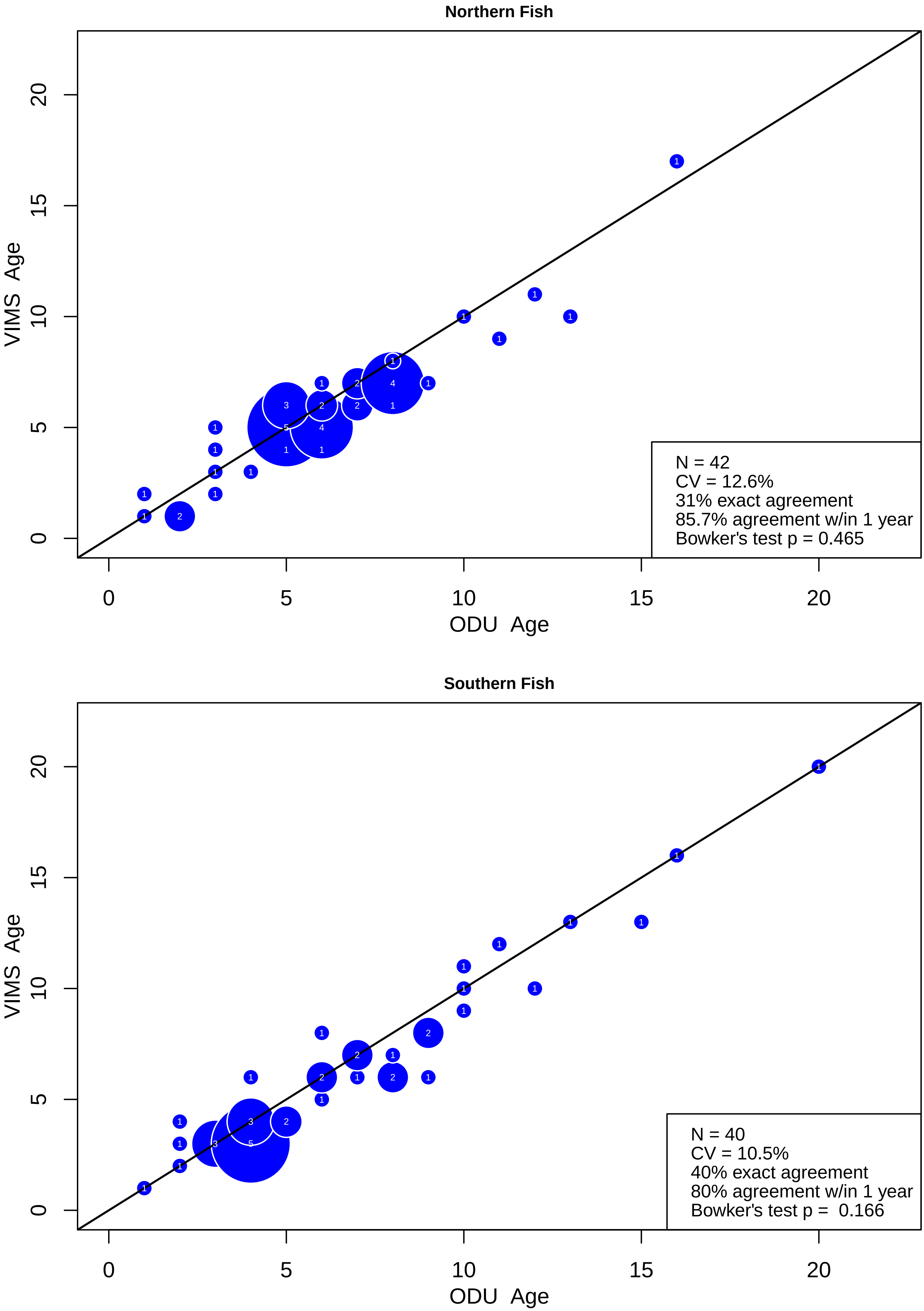
Figure 44: MA vs. CT bias plots by hard part. Circles are proportional to number of observations.



Operculum Ages

Otolith Ages

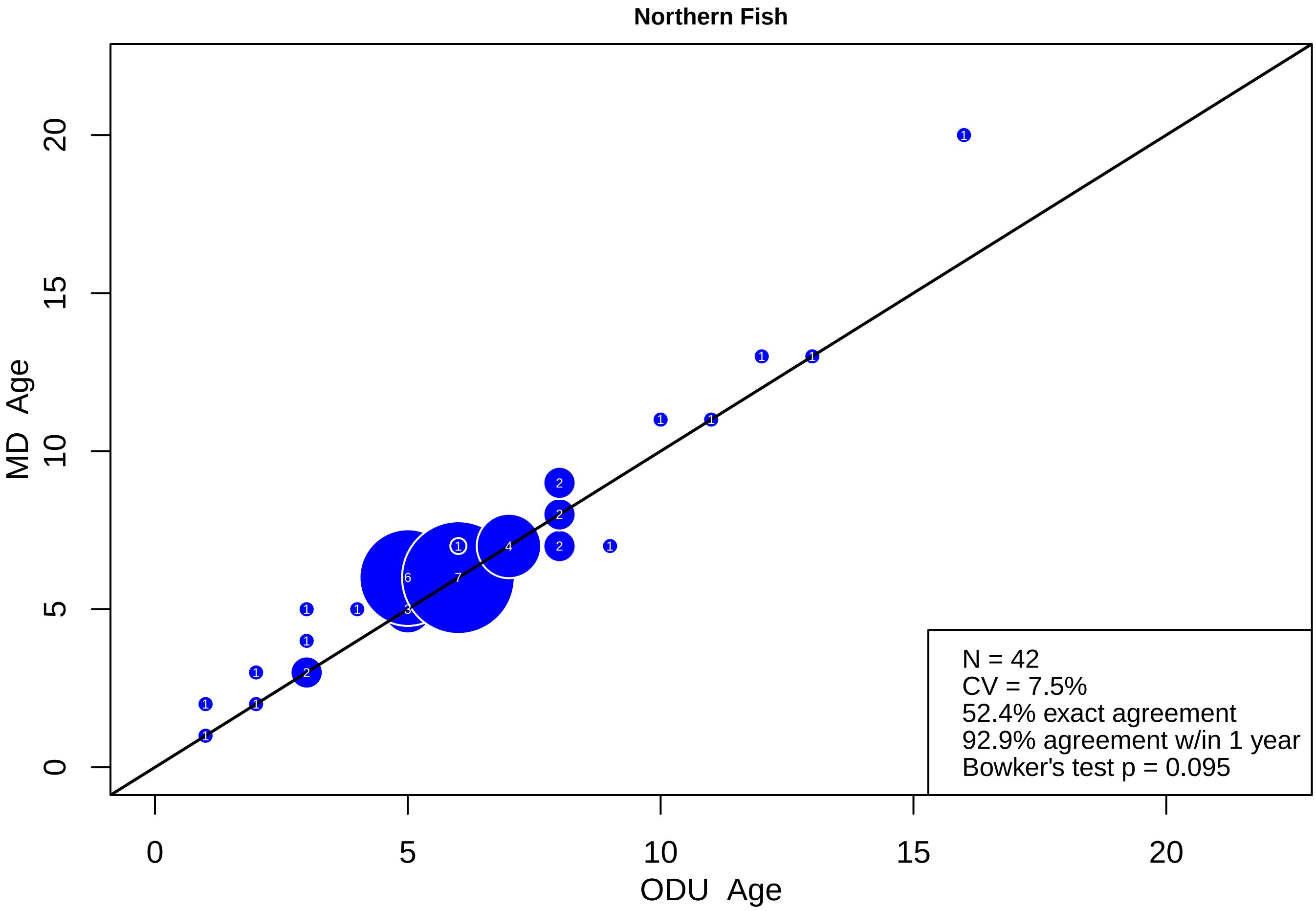
Figure 45: MA vs. RI bias plots by hard part. Circles are proportional to number of observations.



N = 42
CV = 12.6%
31% exact agreement
85.7% agreement w/in 1 year
Bowker's test p = 0.465

N = 40
CV = 10.5%
40% exact agreement
80% agreement w/in 1 year
Bowker's test p = 0.166

Figure 46: VIMS vs. ODU bias plots of operculum ages by region of sample origin.


Northern Fish

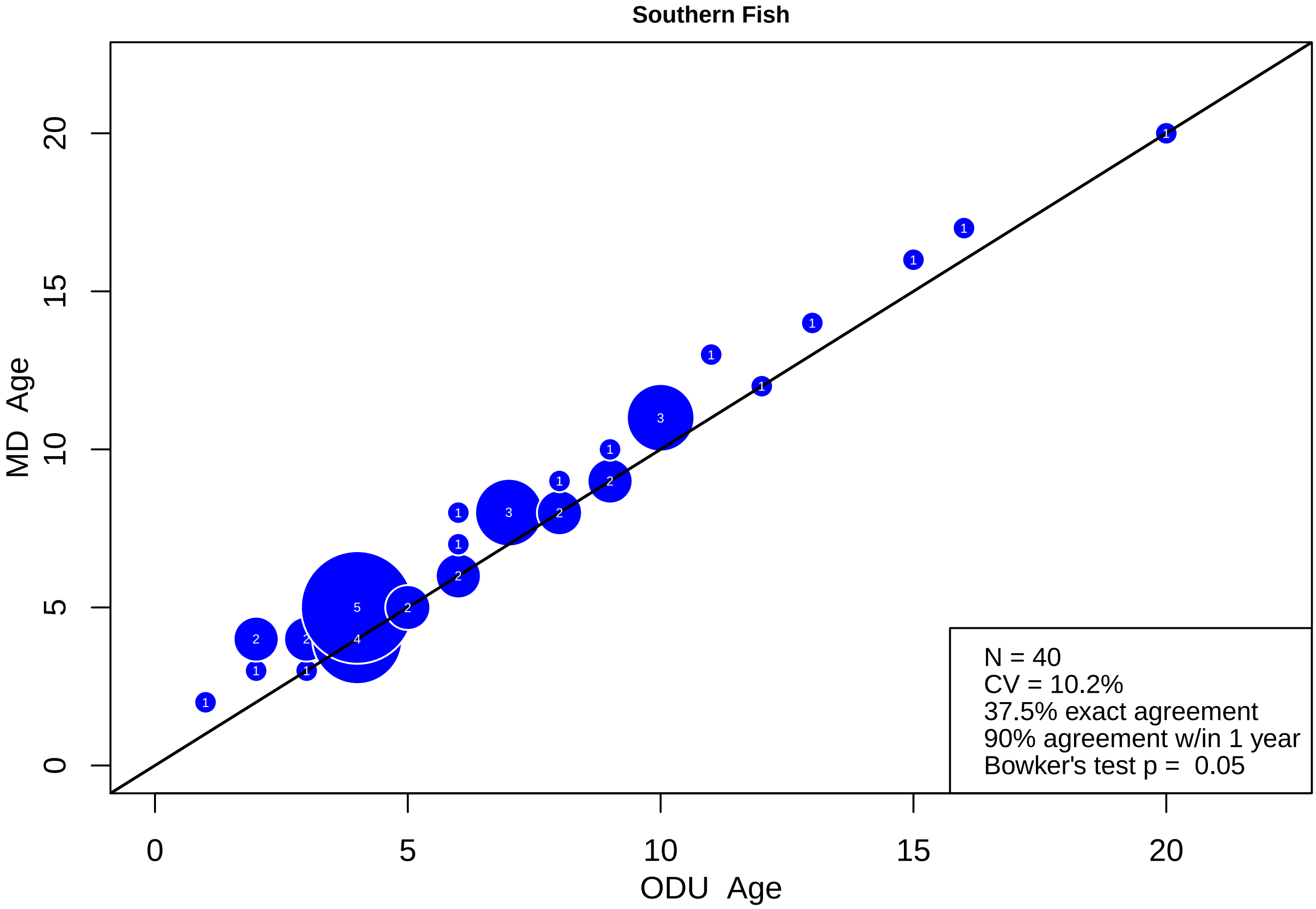
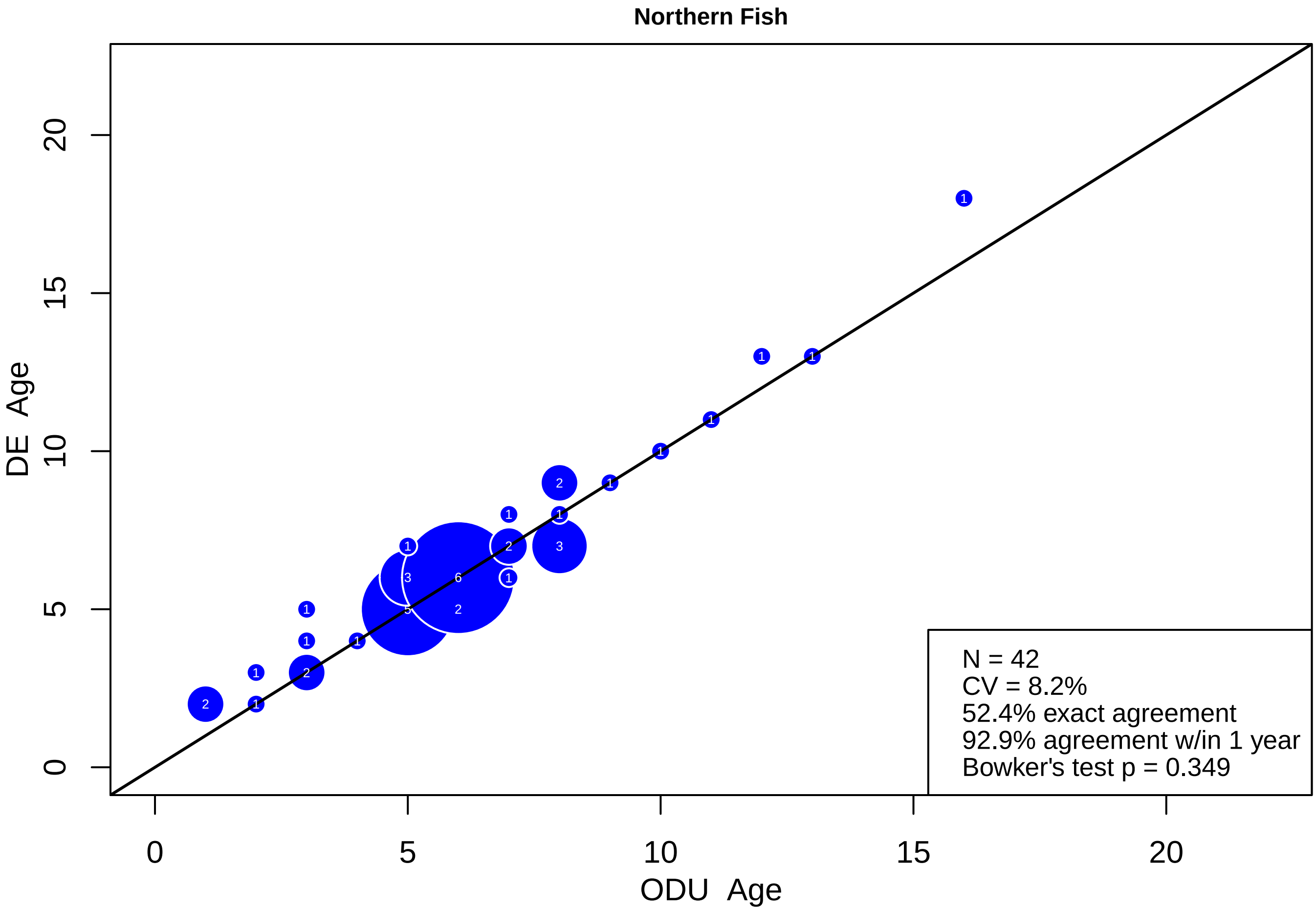

Southern Fish

Figure 47: MD vs. ODU bias plots of operculum ages by region of sample origin.



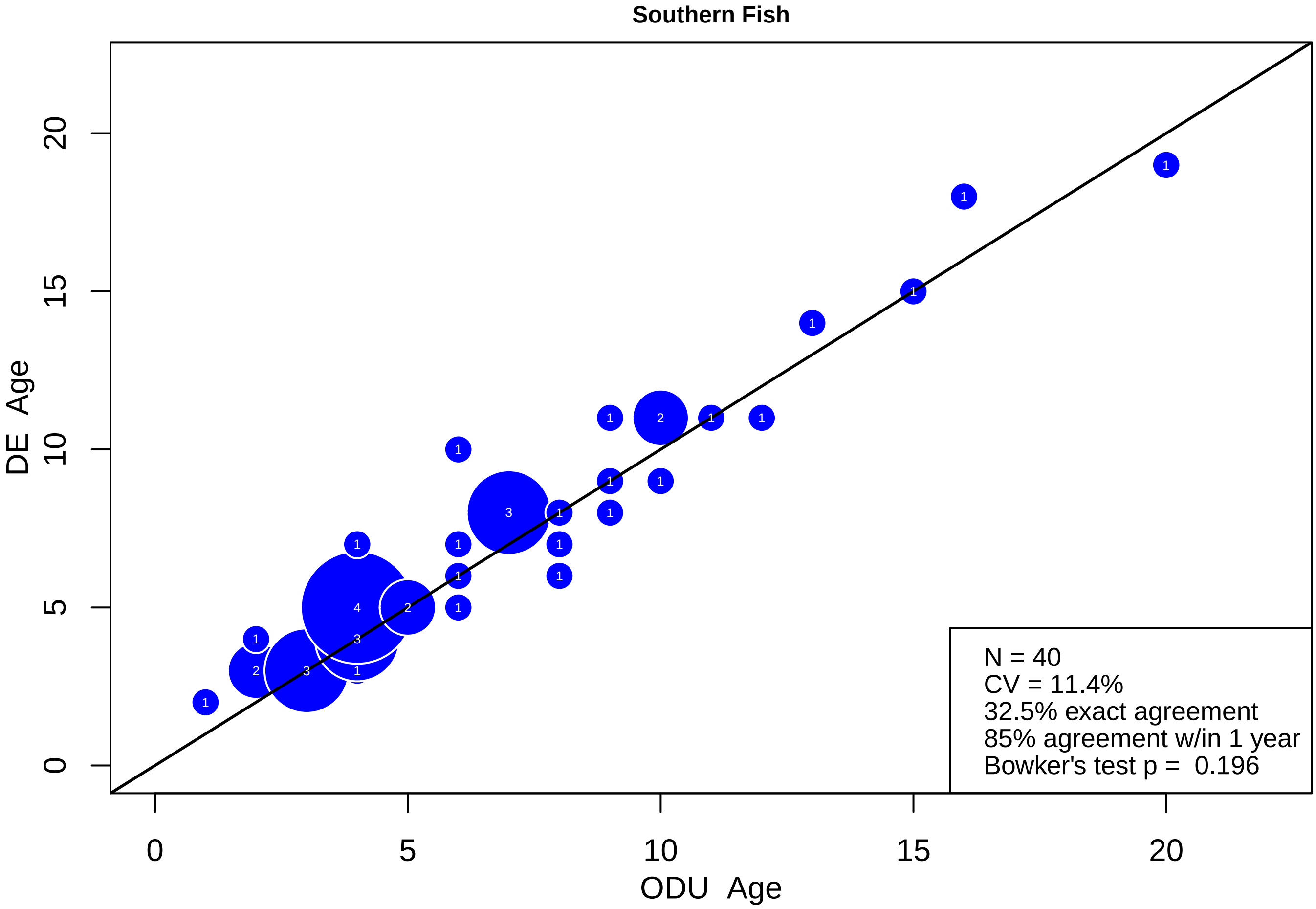


Figure 48: DE vs. ODU bias plots of operculum ages by region of sample origin.

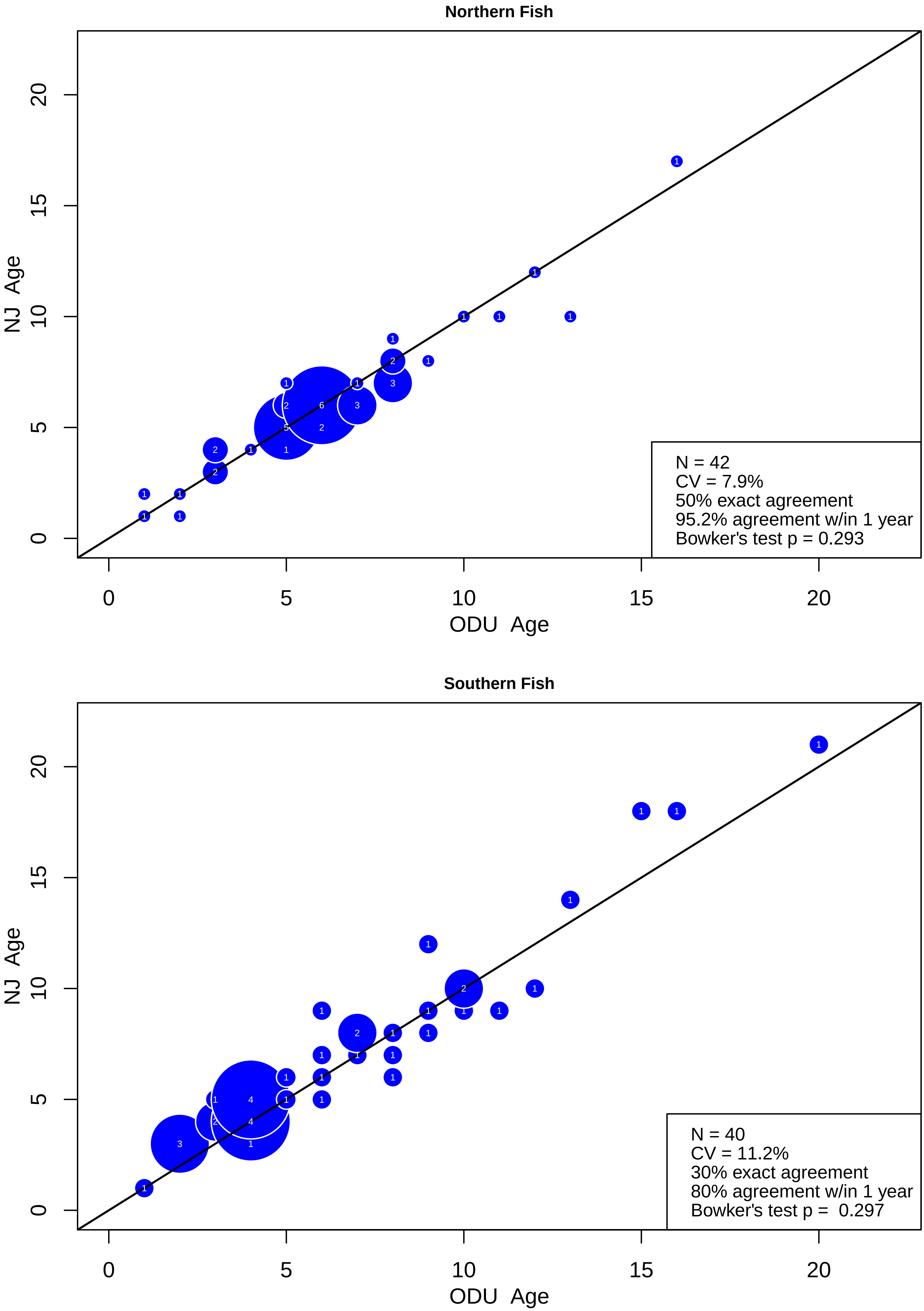
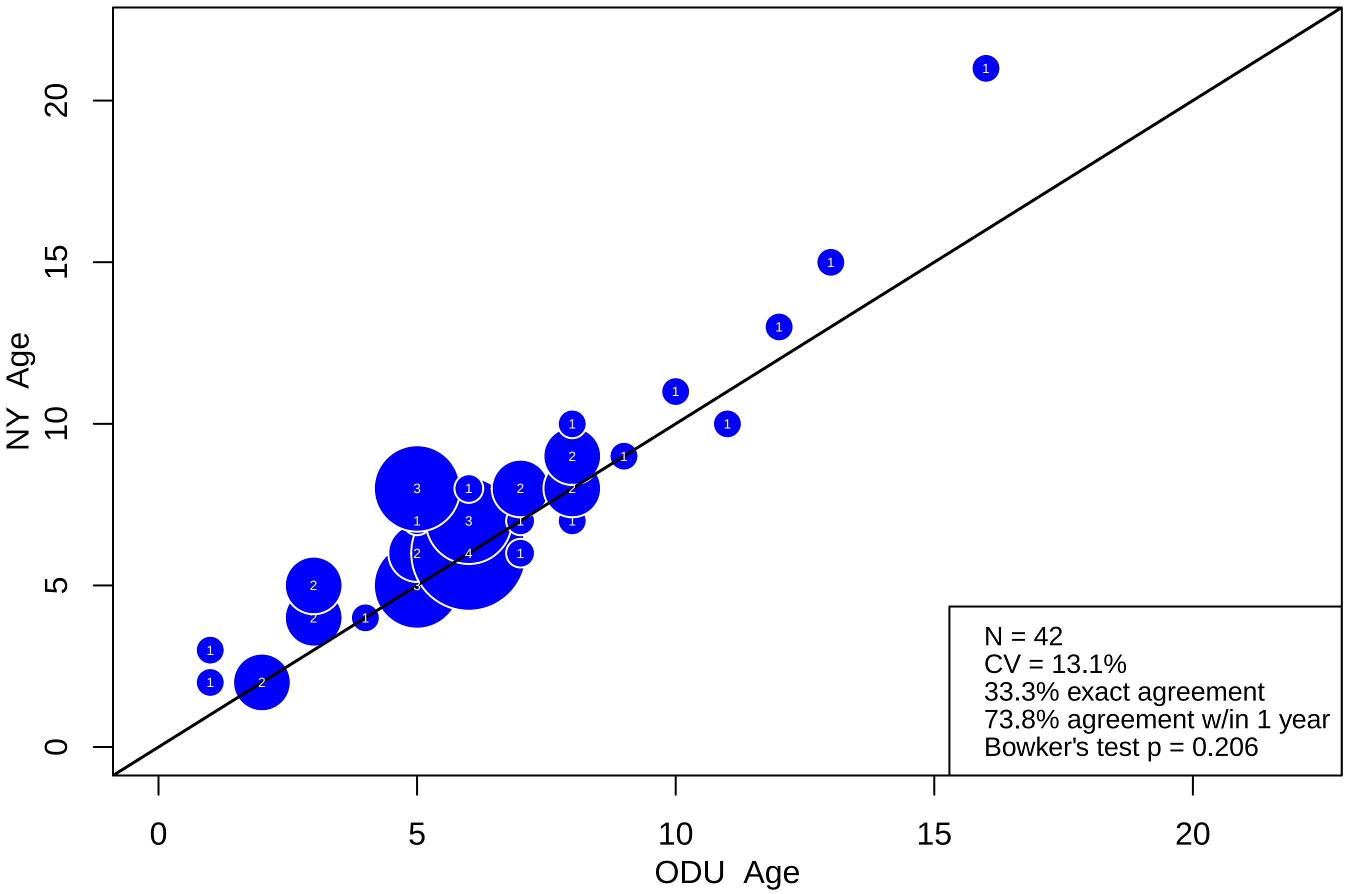


Figure 49: NJ vs. ODU bias plots of operculum ages by region of sample origin.

Northern Fish



Southern Fish

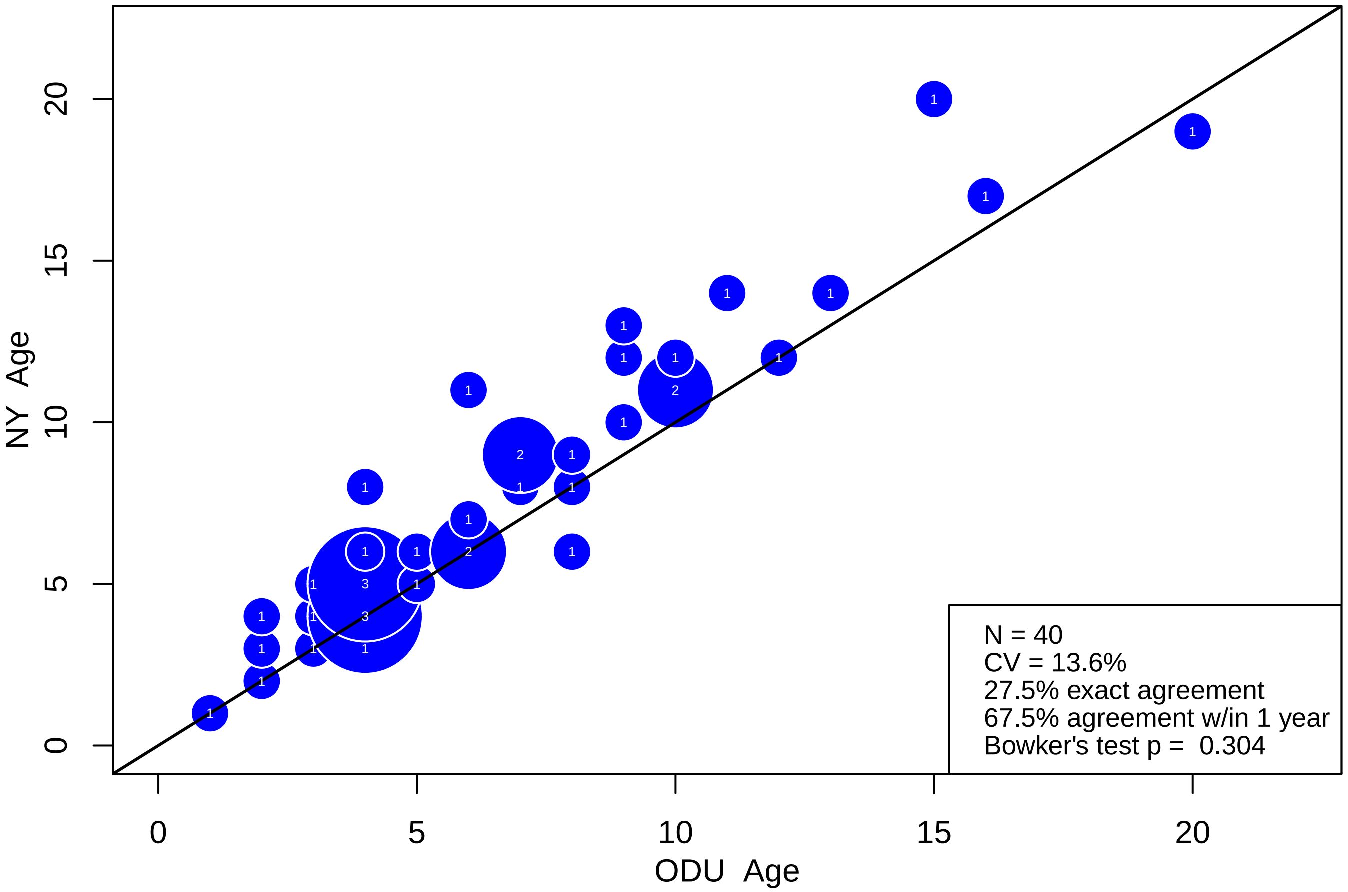


Figure 50: NY vs. ODU bias plots of operculum ages by region of sample origin.

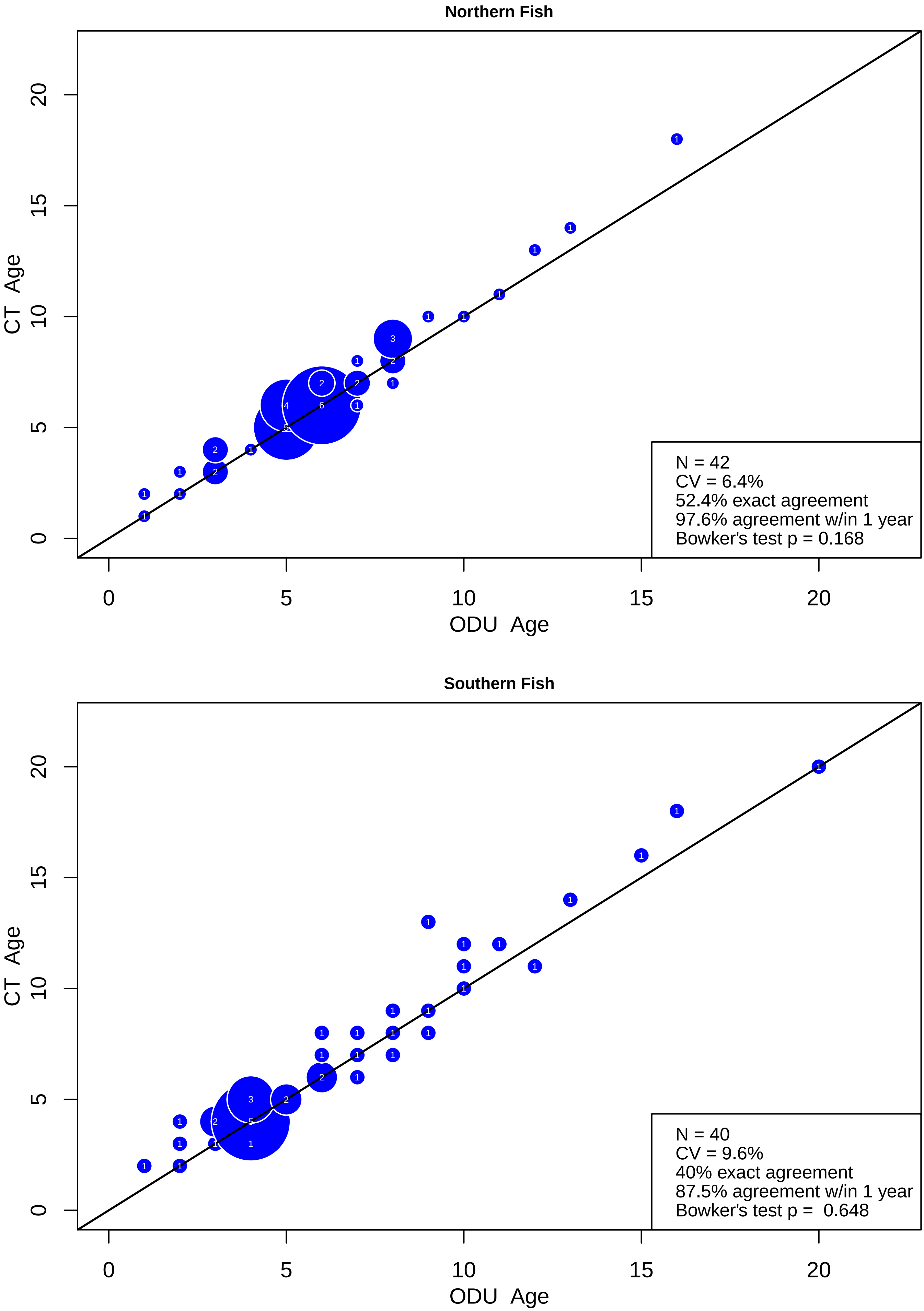


Figure 51: CT vs. ODU bias plots of operculum ages by region of sample origin.

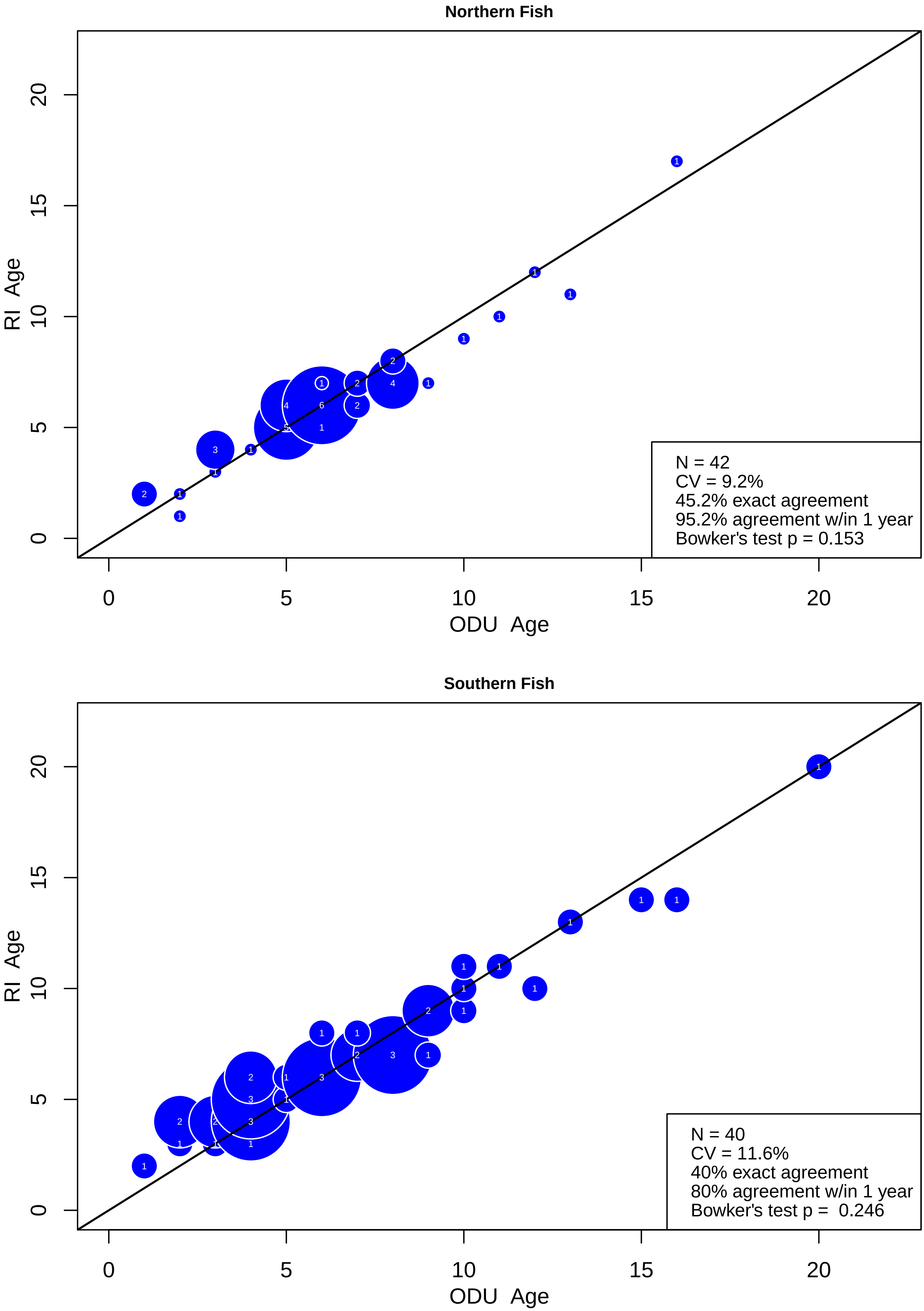


Figure 52: RI vs. ODU bias plots of operculum ages by region of sample origin.

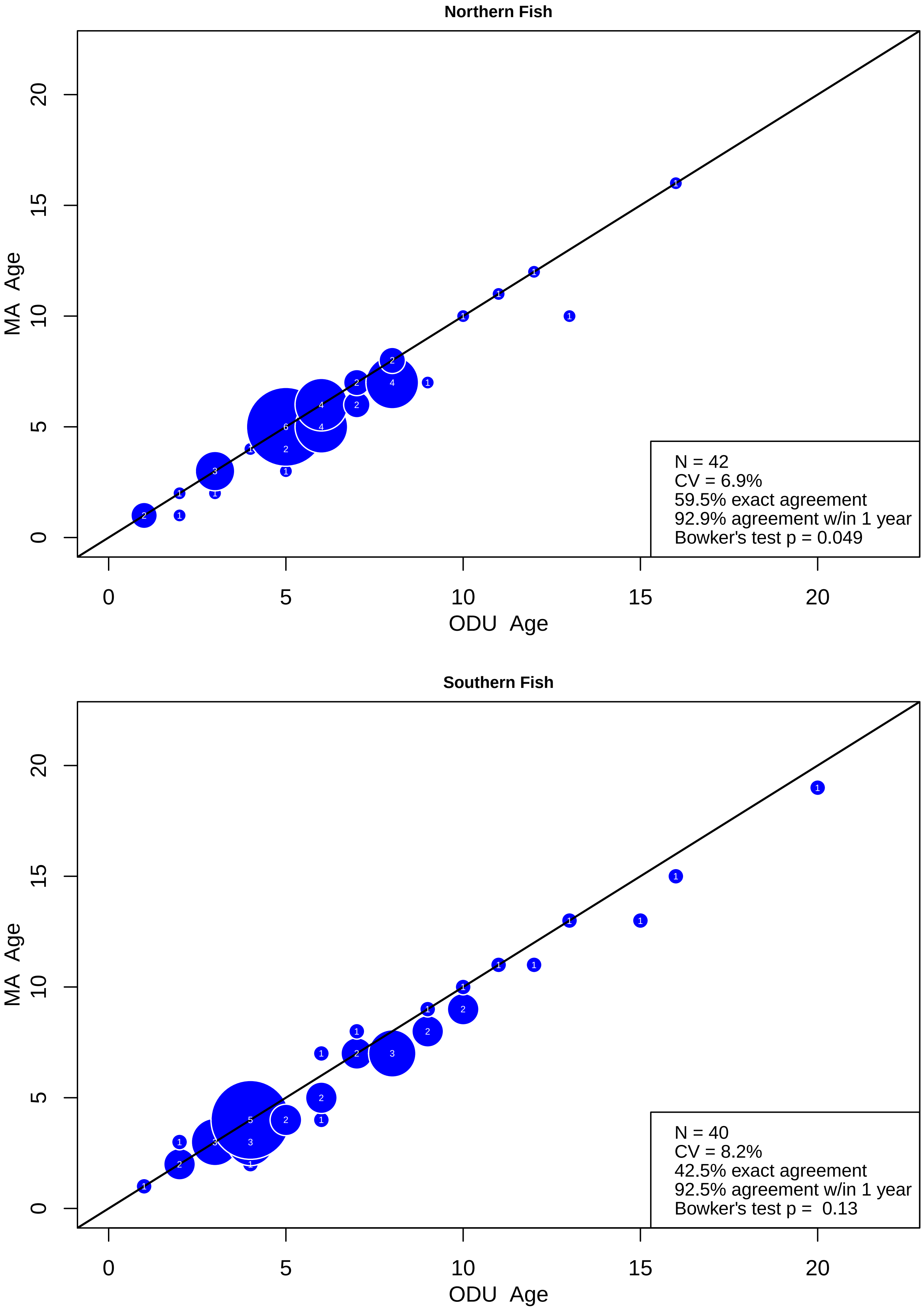
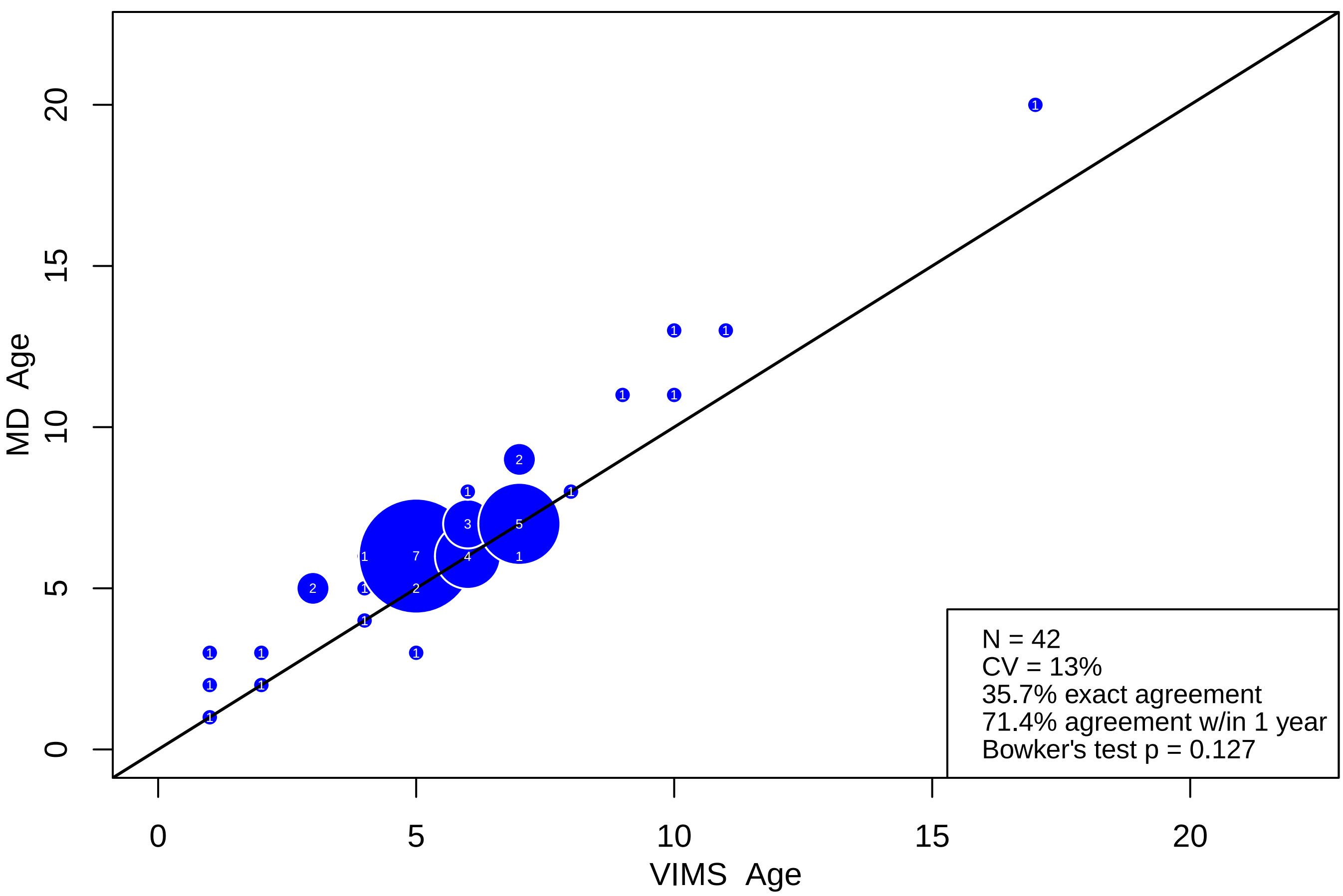


Figure 53: MA vs. ODU bias plots of operculum ages by region of sample origin.


Northern Fish

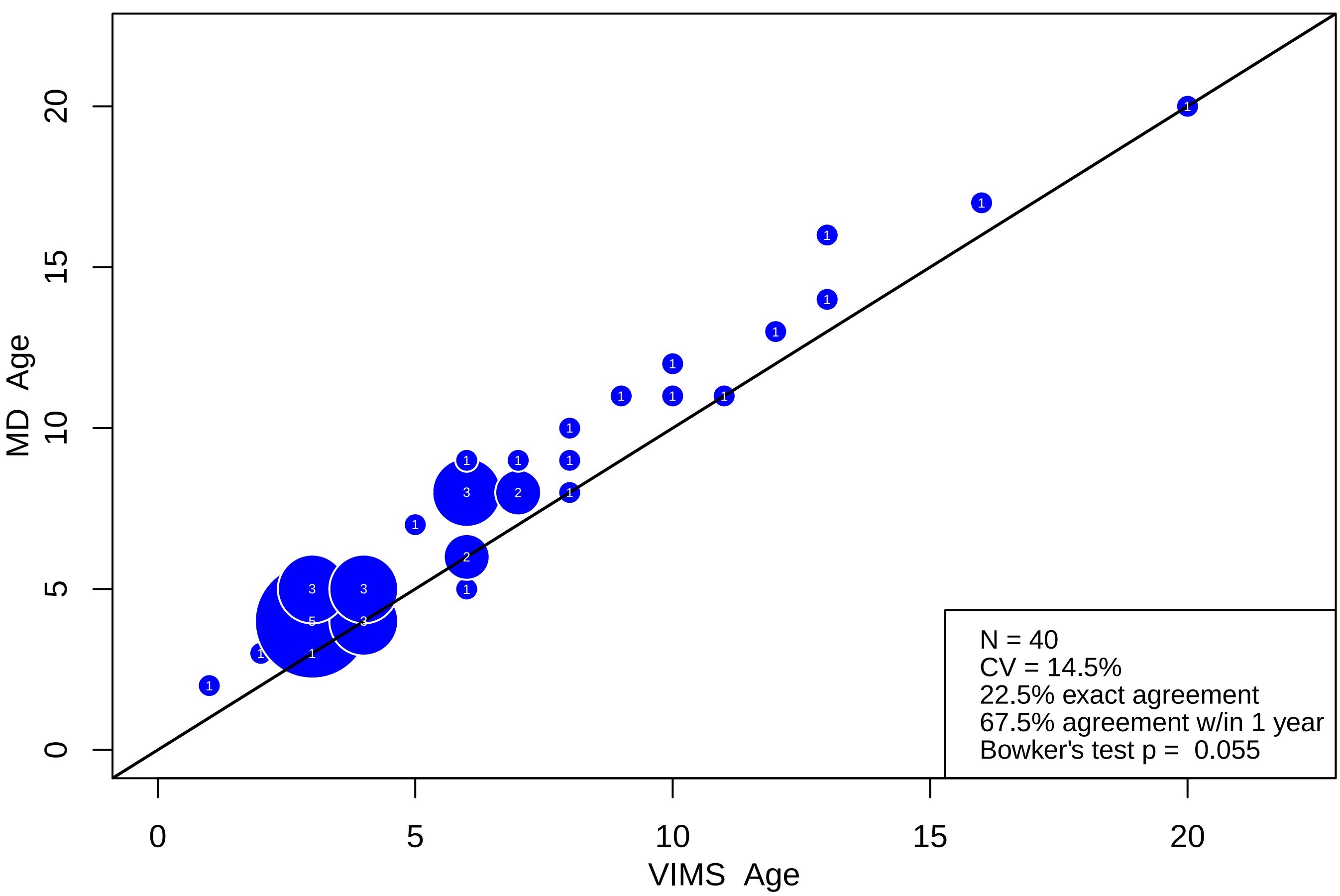

Southern Fish

Figure 54: MD vs. VIMS bias plots of operculum ages by region of sample origin.

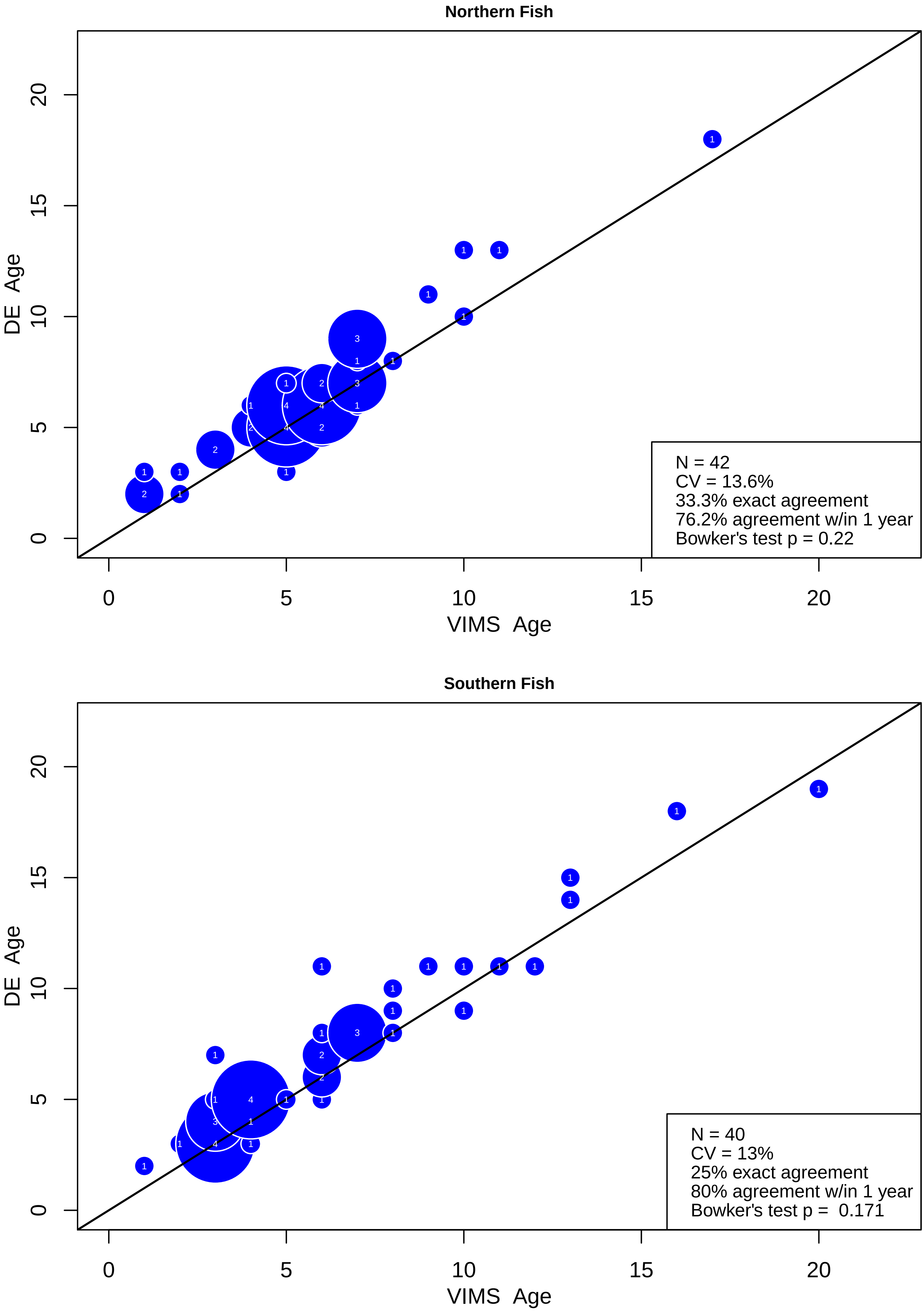


Figure 55: DE vs. VIMS bias plots of operculum ages by region of sample origin.

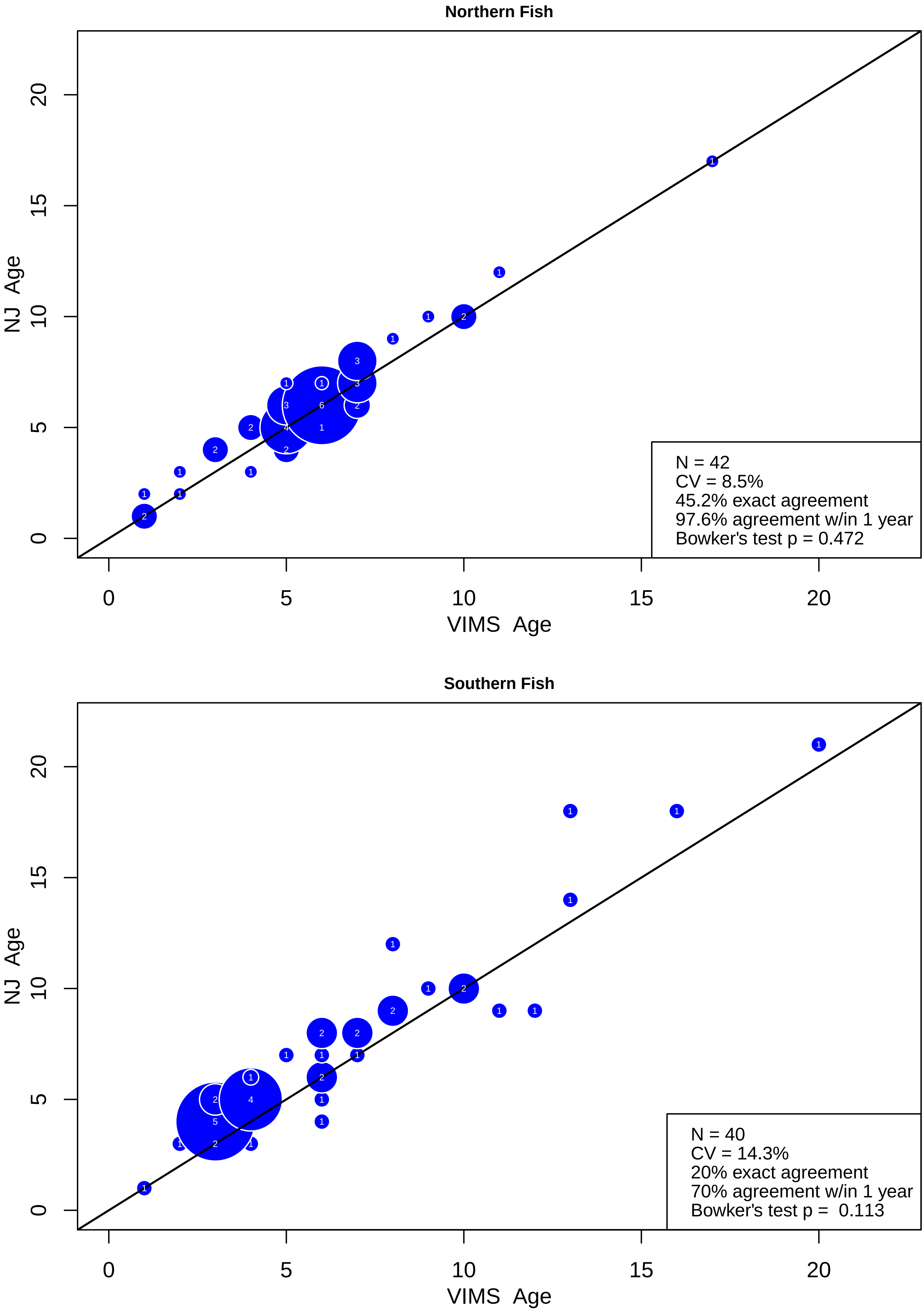


Figure 56: NJ vs. VIMS bias plots of operculum ages by region of sample origin.

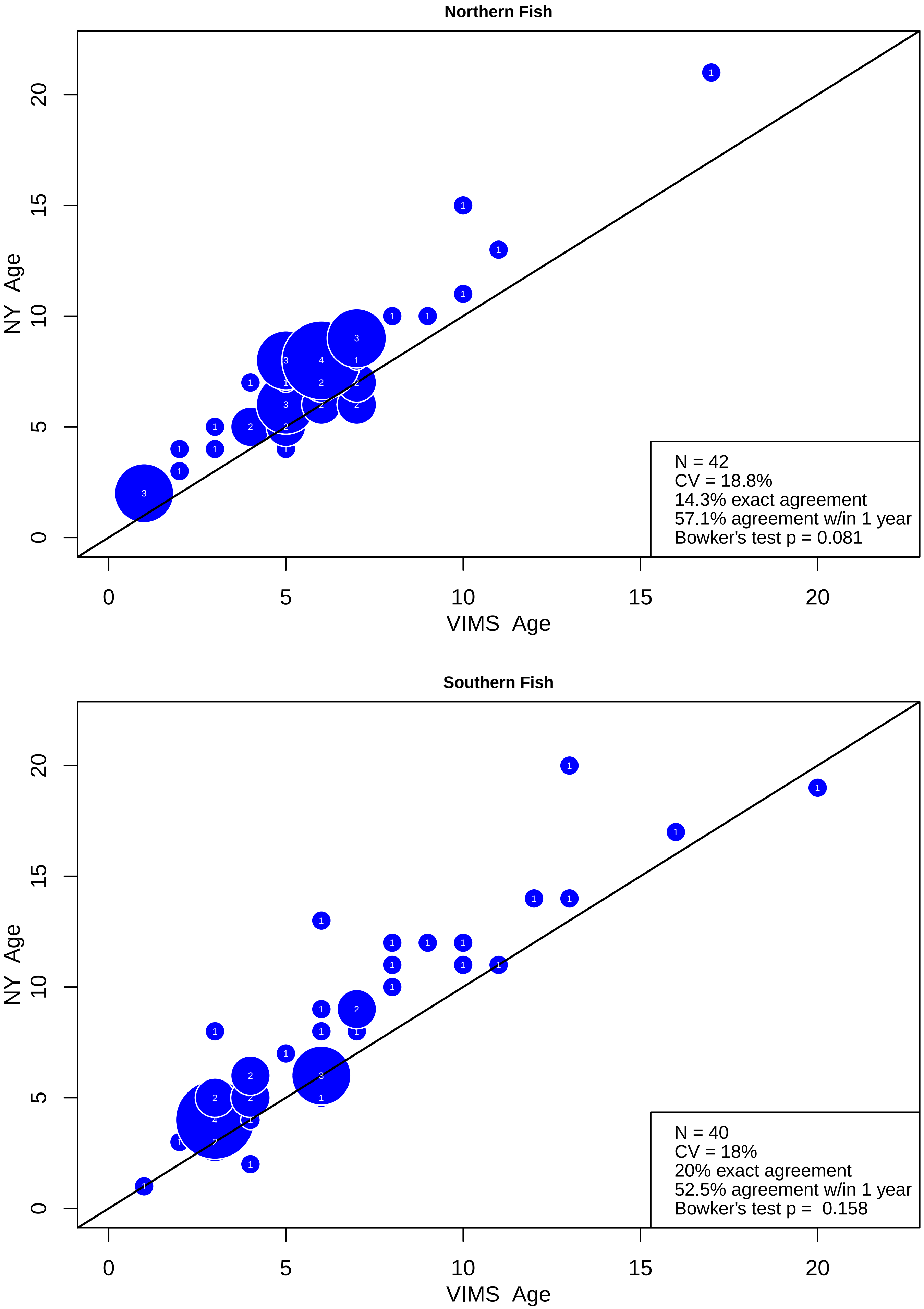


Figure 57: NY vs. VIMS bias plots of operculum ages by region of sample origin.

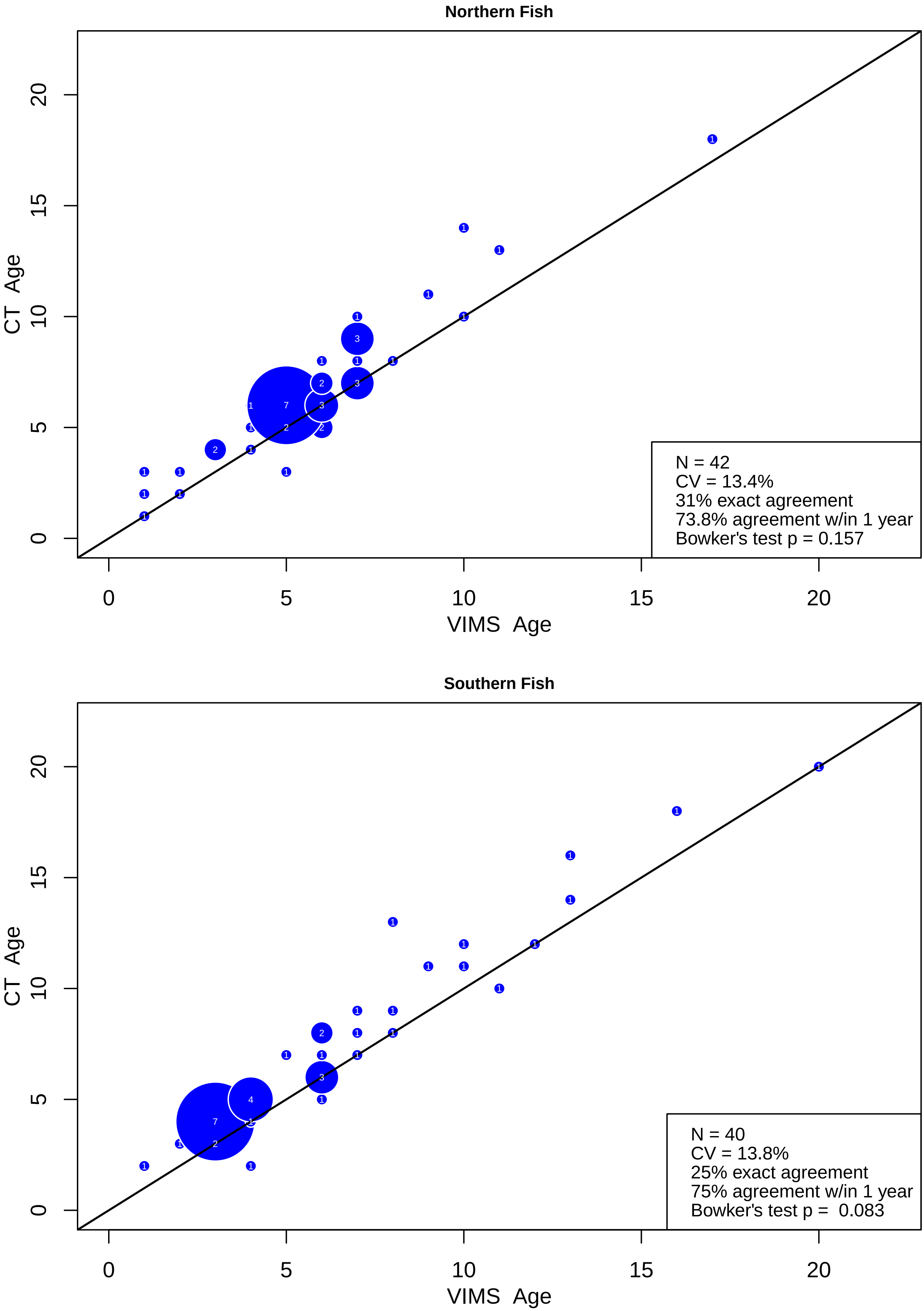


Figure 58: CT vs. VIMS bias plots of operculum ages by region of sample origin.

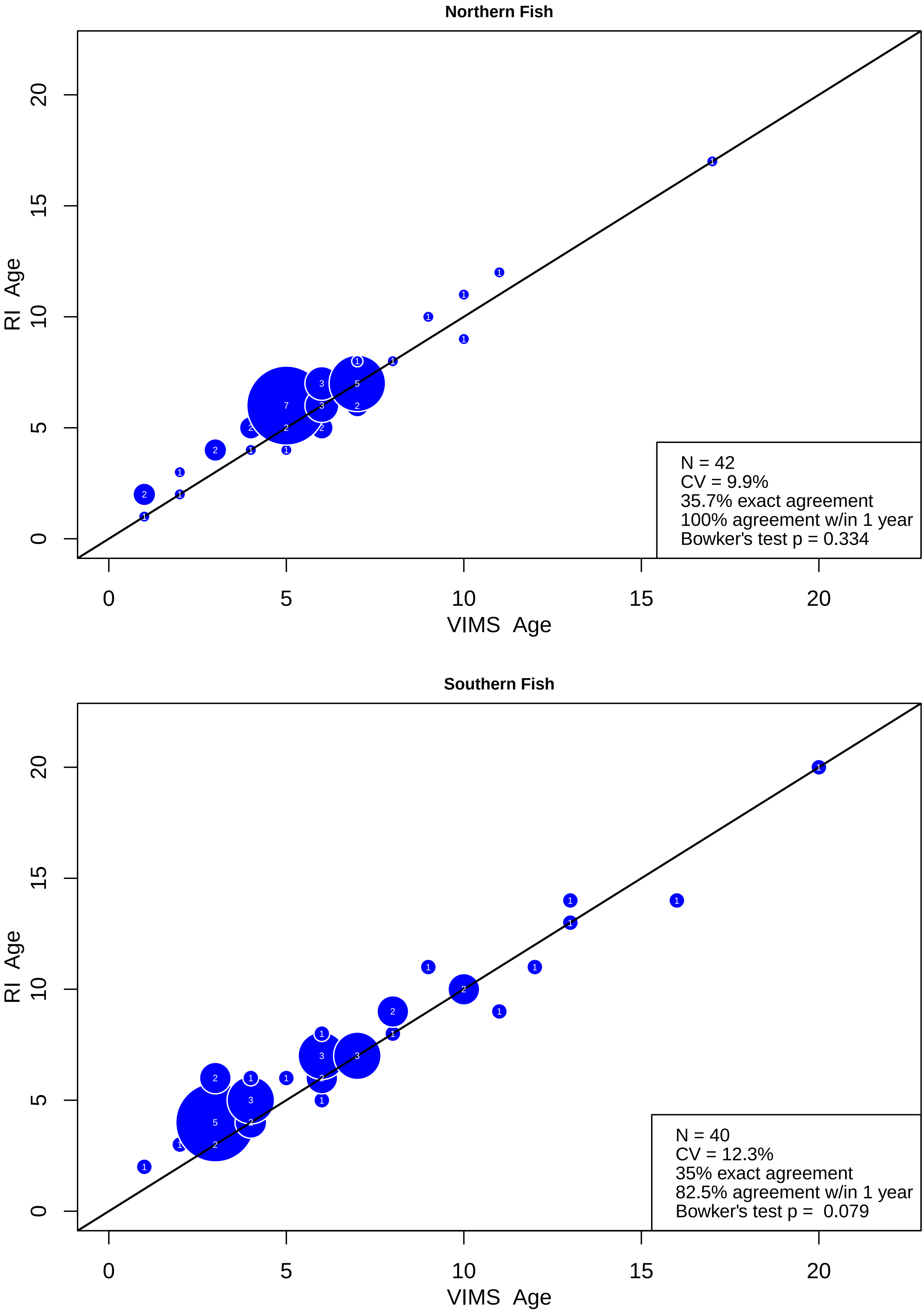
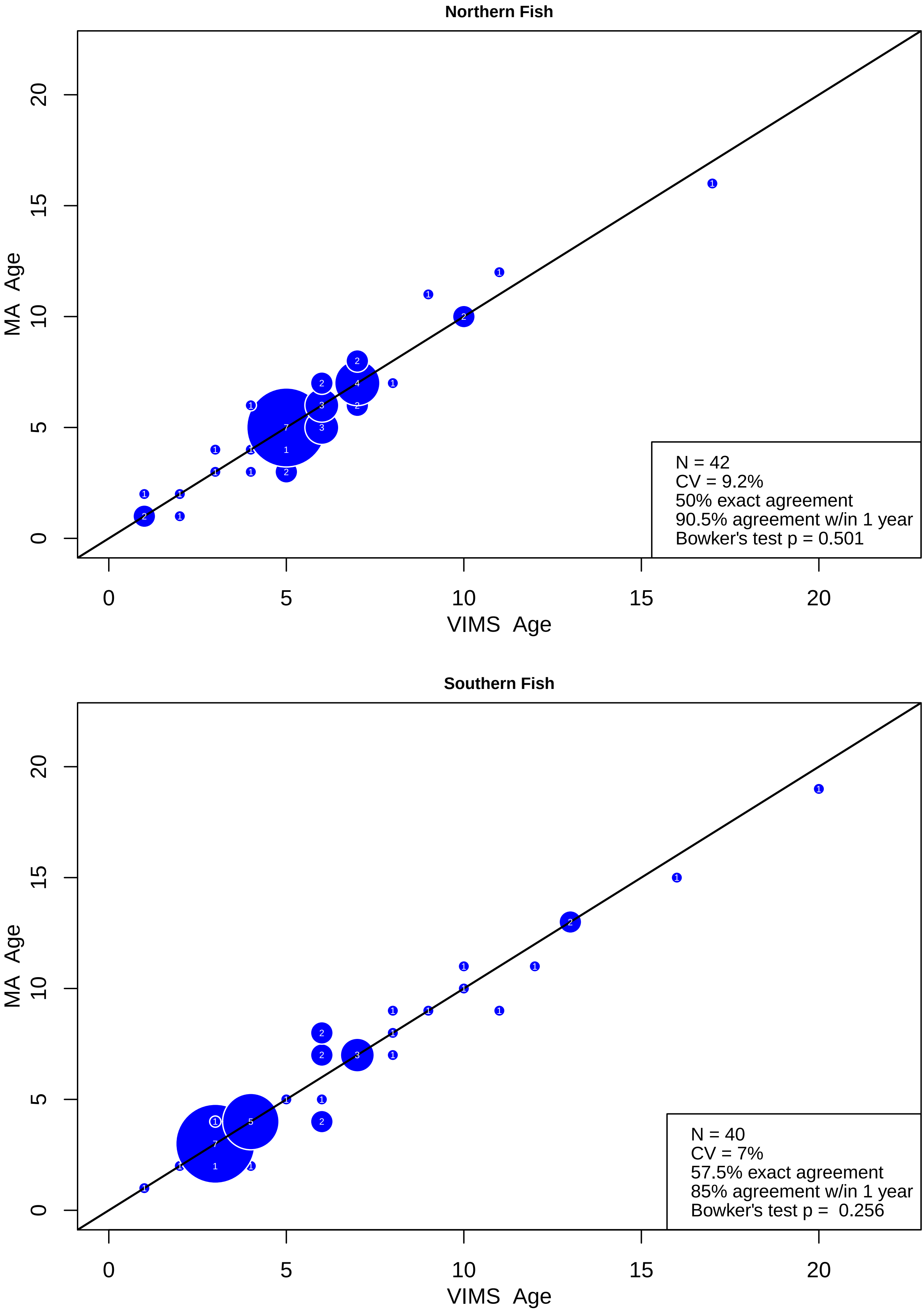


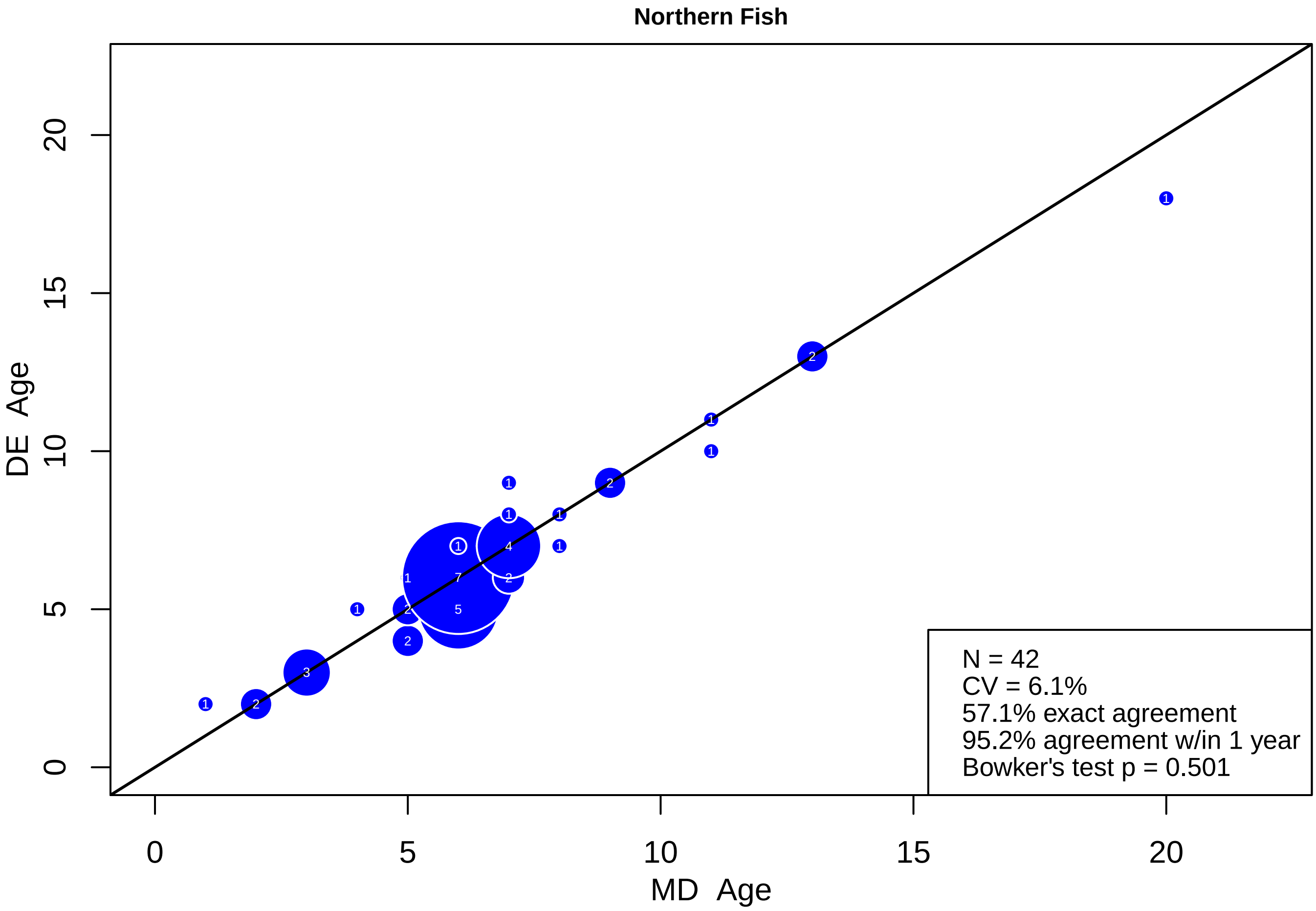
Figure 59: RI vs. VIMS bias plots of operculum ages by region of sample origin.



N = 42
CV = 9.2%
50% exact agreement
90.5% agreement w/in 1 year
Bowker's test p = 0.501

N = 40
CV = 7%
57.5% exact agreement
85% agreement w/in 1 year
Bowker's test p = 0.256

Figure 60: MA vs. VIMS bias plots of operculum ages by region of sample origin.



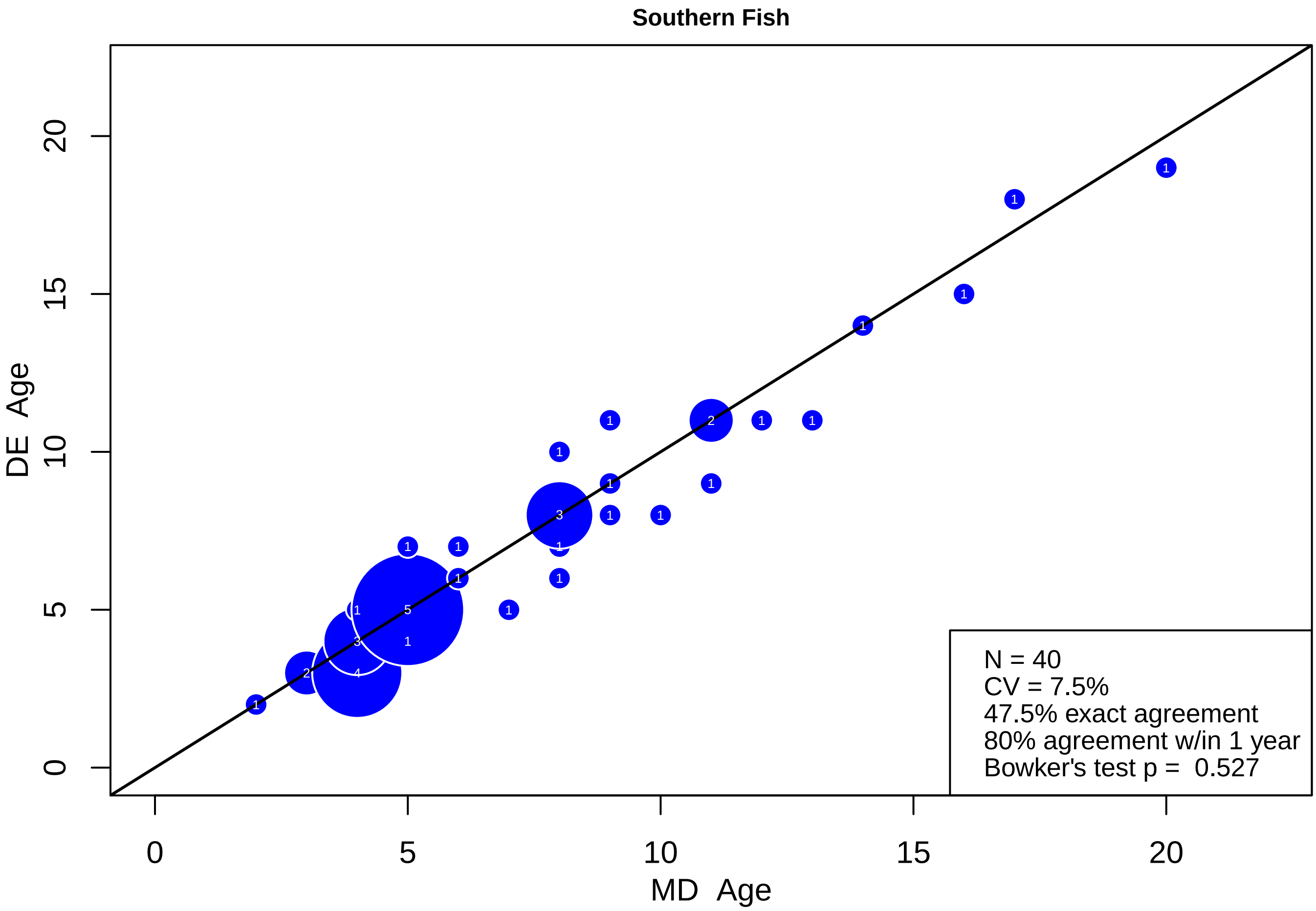


Figure 61: DE vs. MD bias plots of operculum ages by region of sample origin.

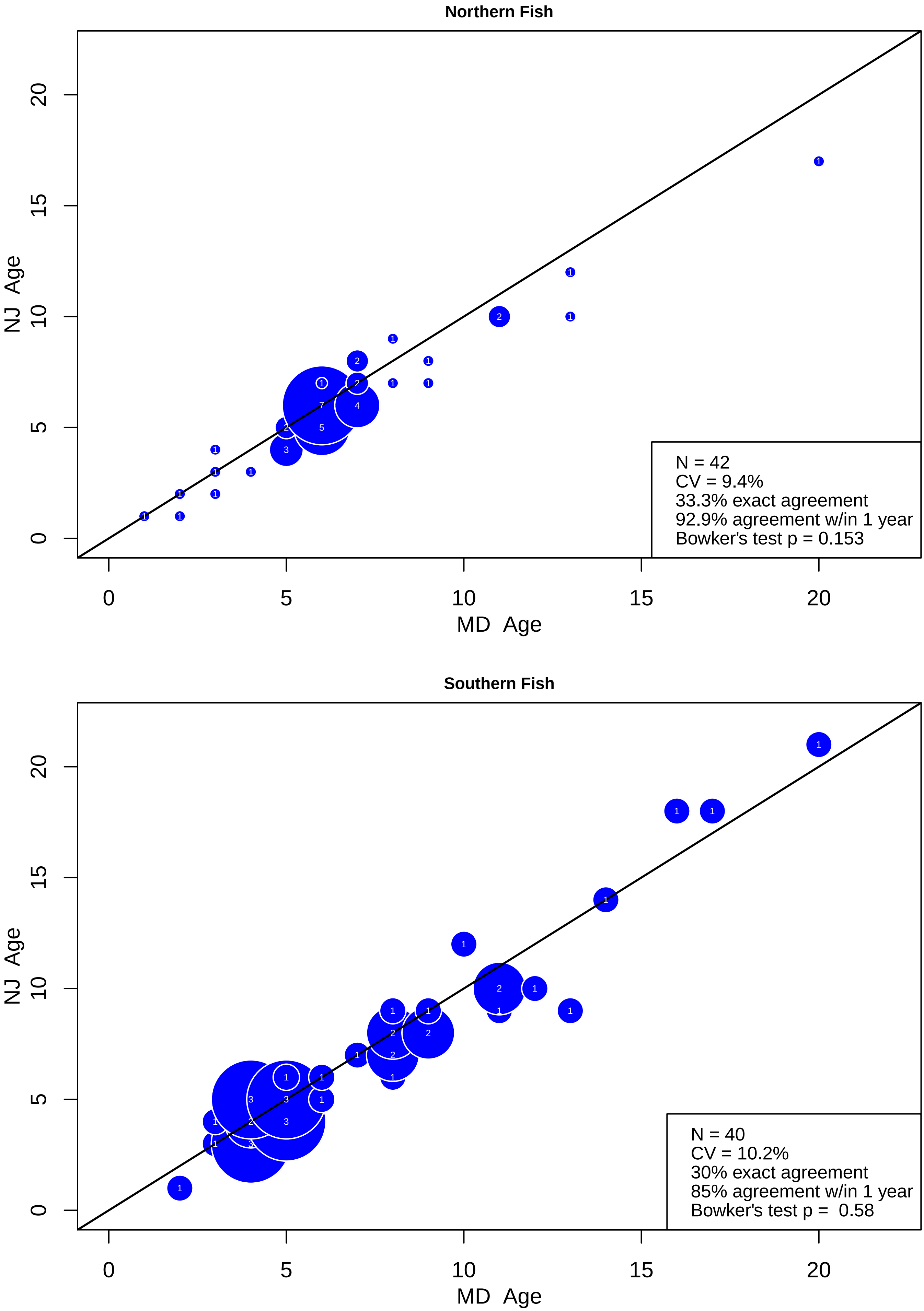


Figure 62: NJ vs. MD bias plots of operculum ages by region of sample origin.

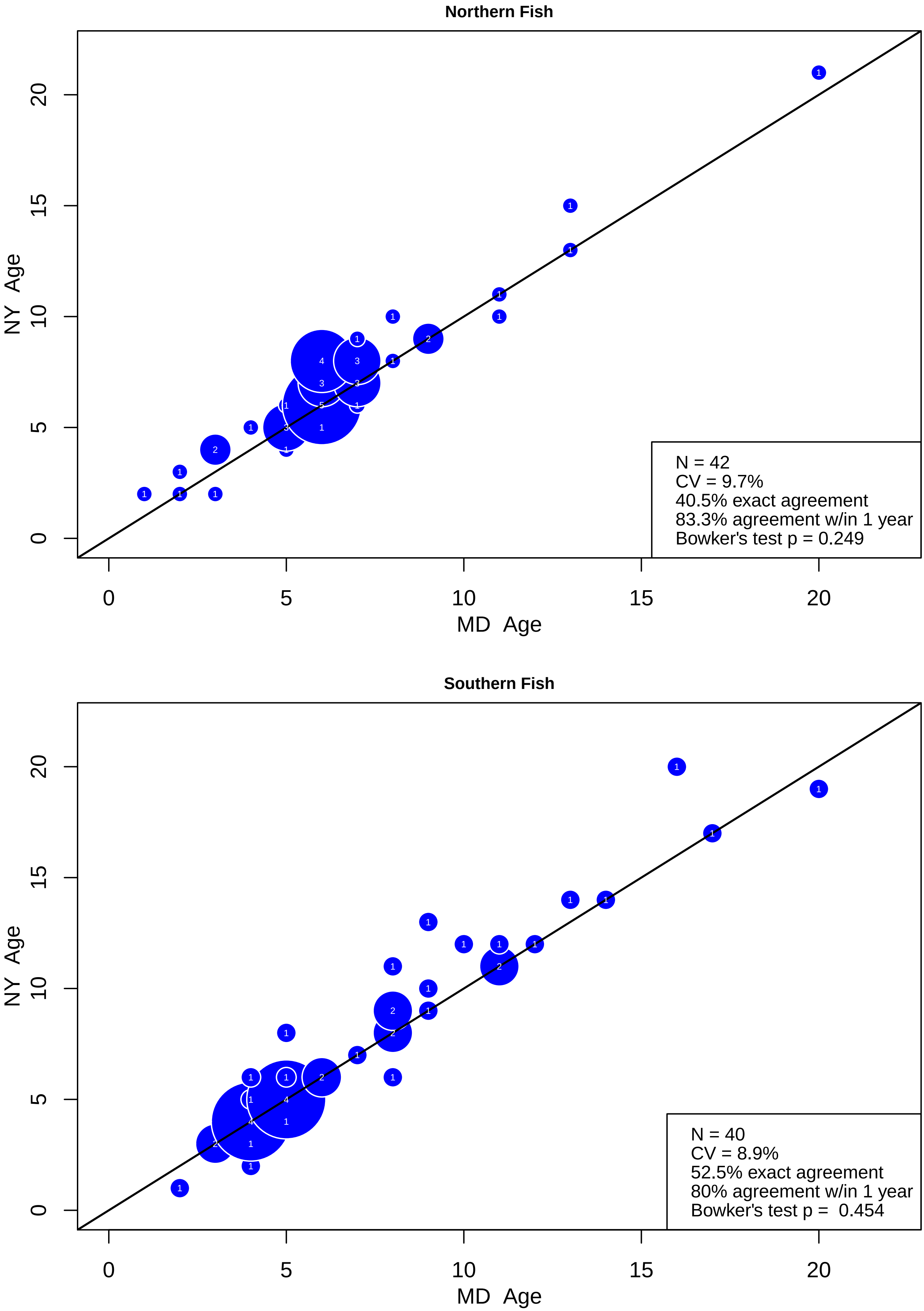


Figure 63: NY vs. MD bias plots of operculum ages by region of sample origin.

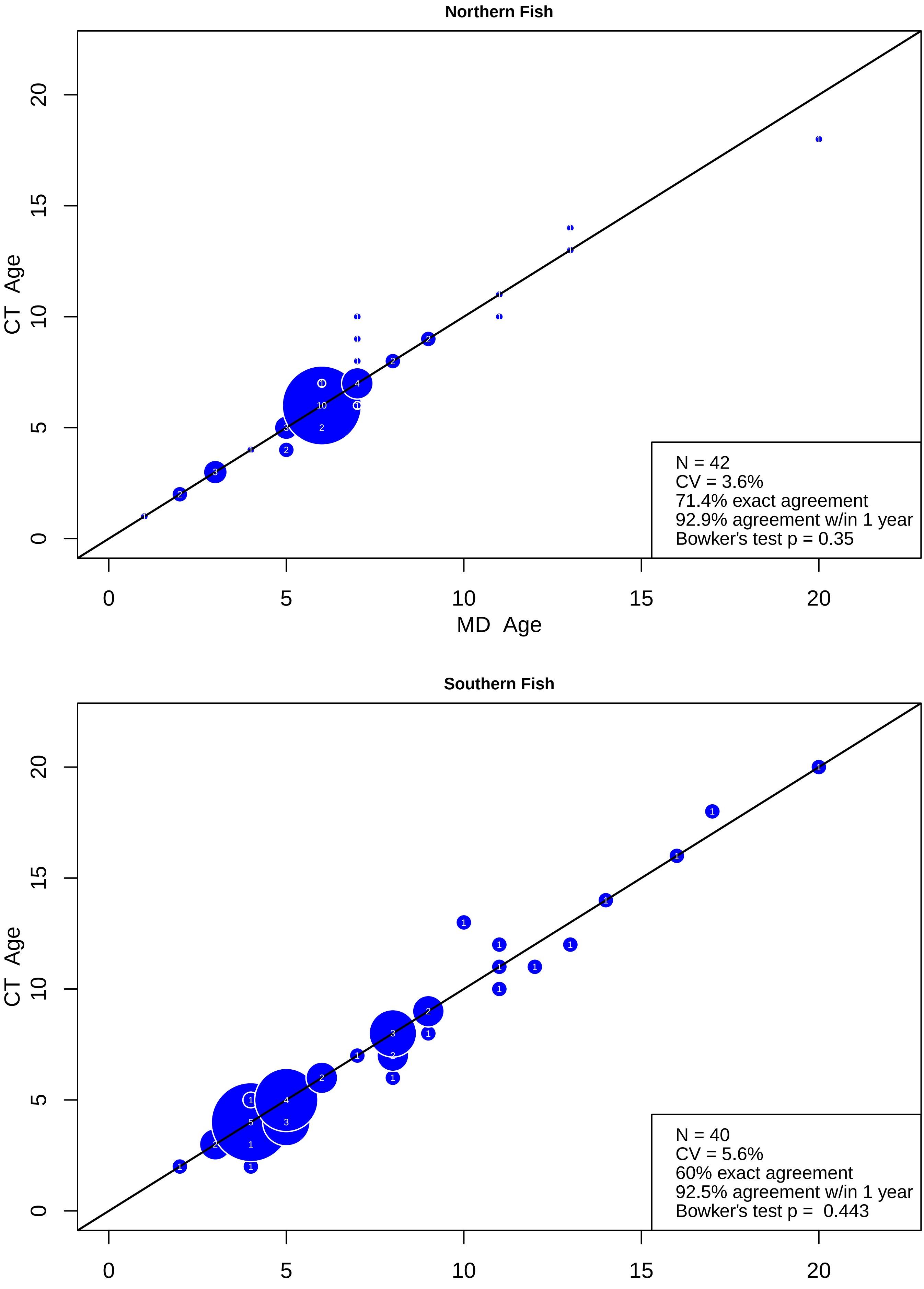
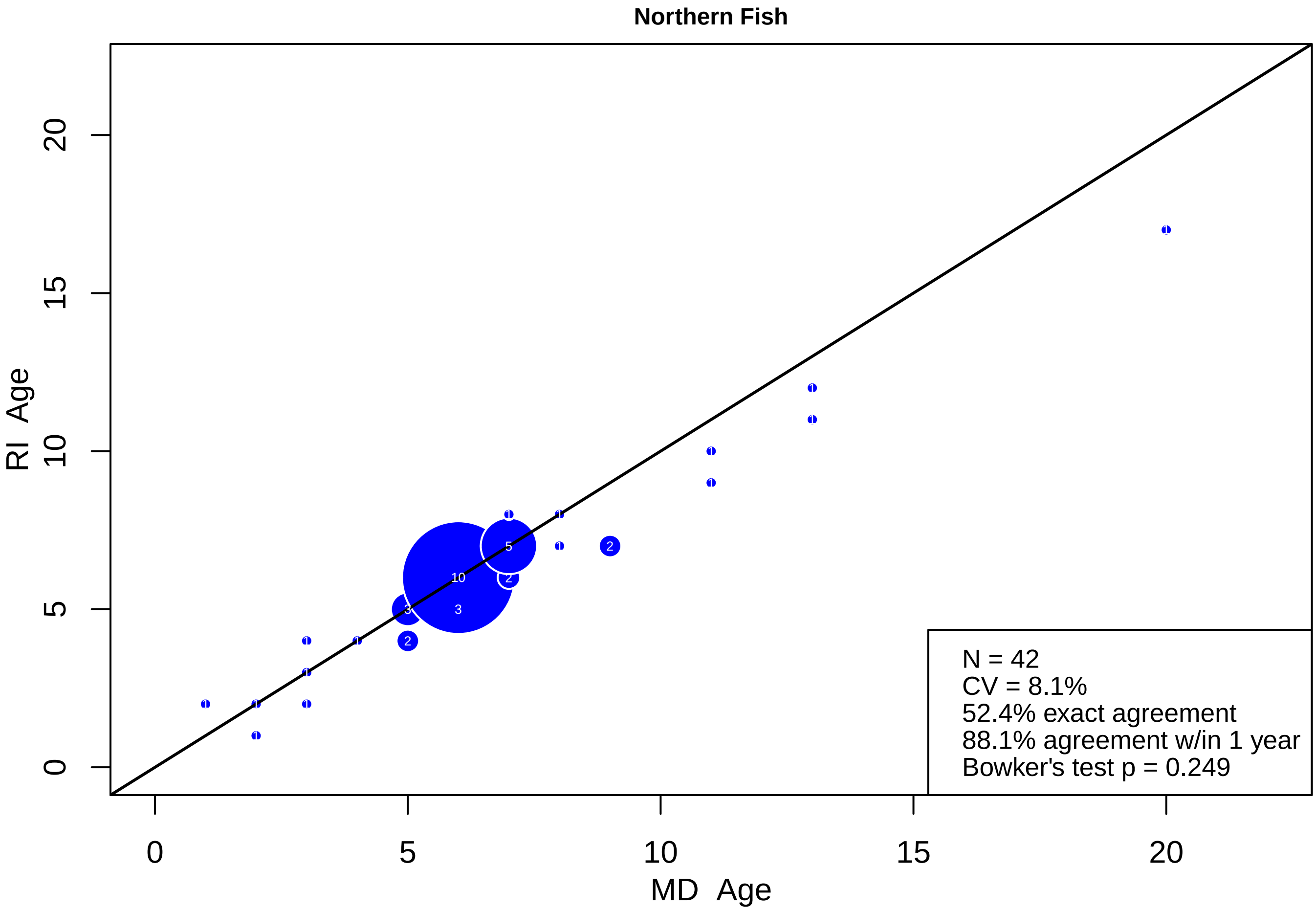
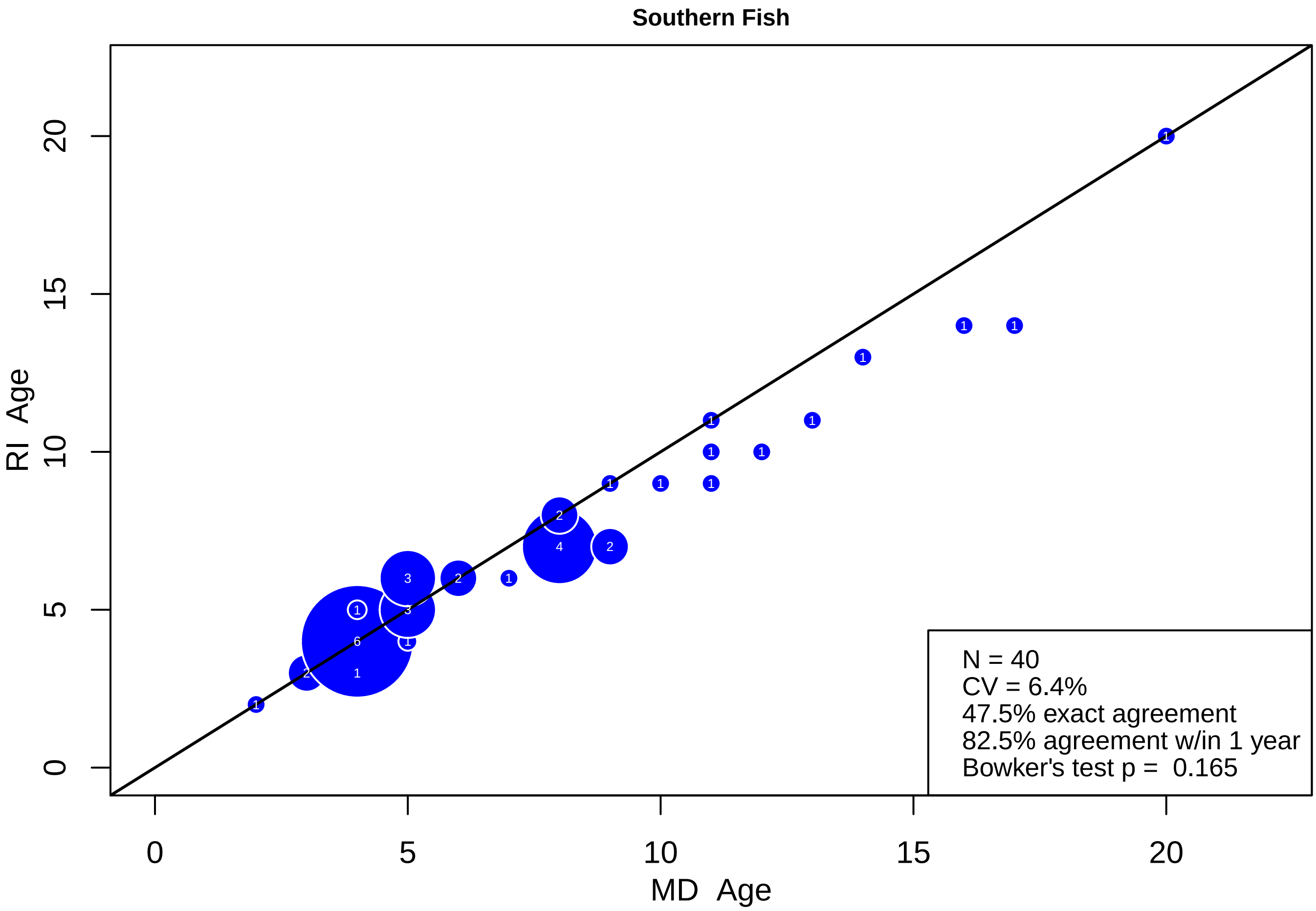


Figure 64: CT vs. MD bias plots of operculum ages by region of sample origin.



Northern Fish

N = 42
CV = 8.1%
52.4% exact agreement
88.1% agreement w/in 1 year
Bowker's test p = 0.249



Southern Fish

N = 40
CV = 6.4%
47.5% exact agreement
82.5% agreement w/in 1 year
Bowker's test p = 0.165

Figure 65: RI vs. MD bias plots of operculum ages by region of sample origin.

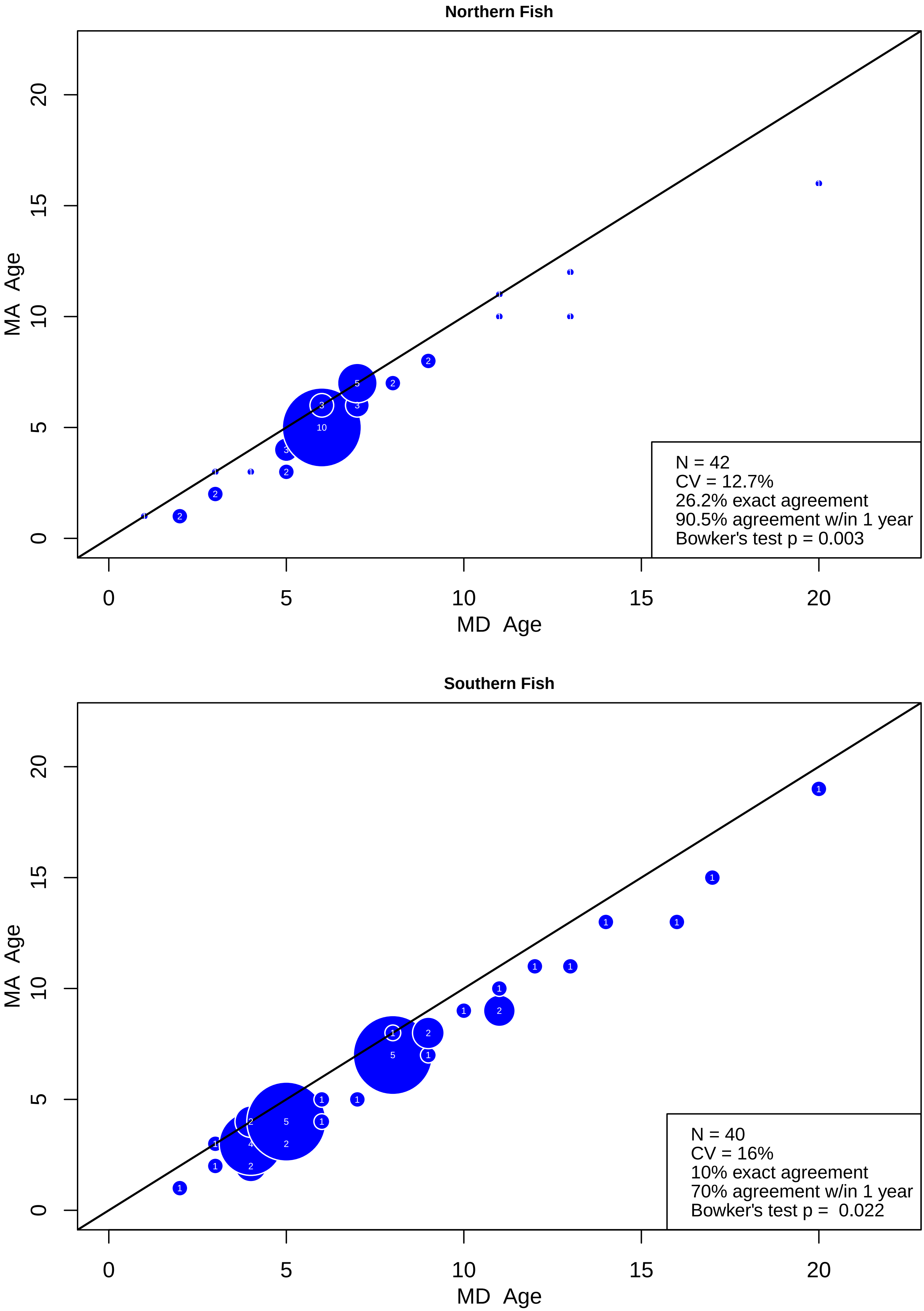


Figure 66: MA vs. MD bias plots of operculum ages by region of sample origin.

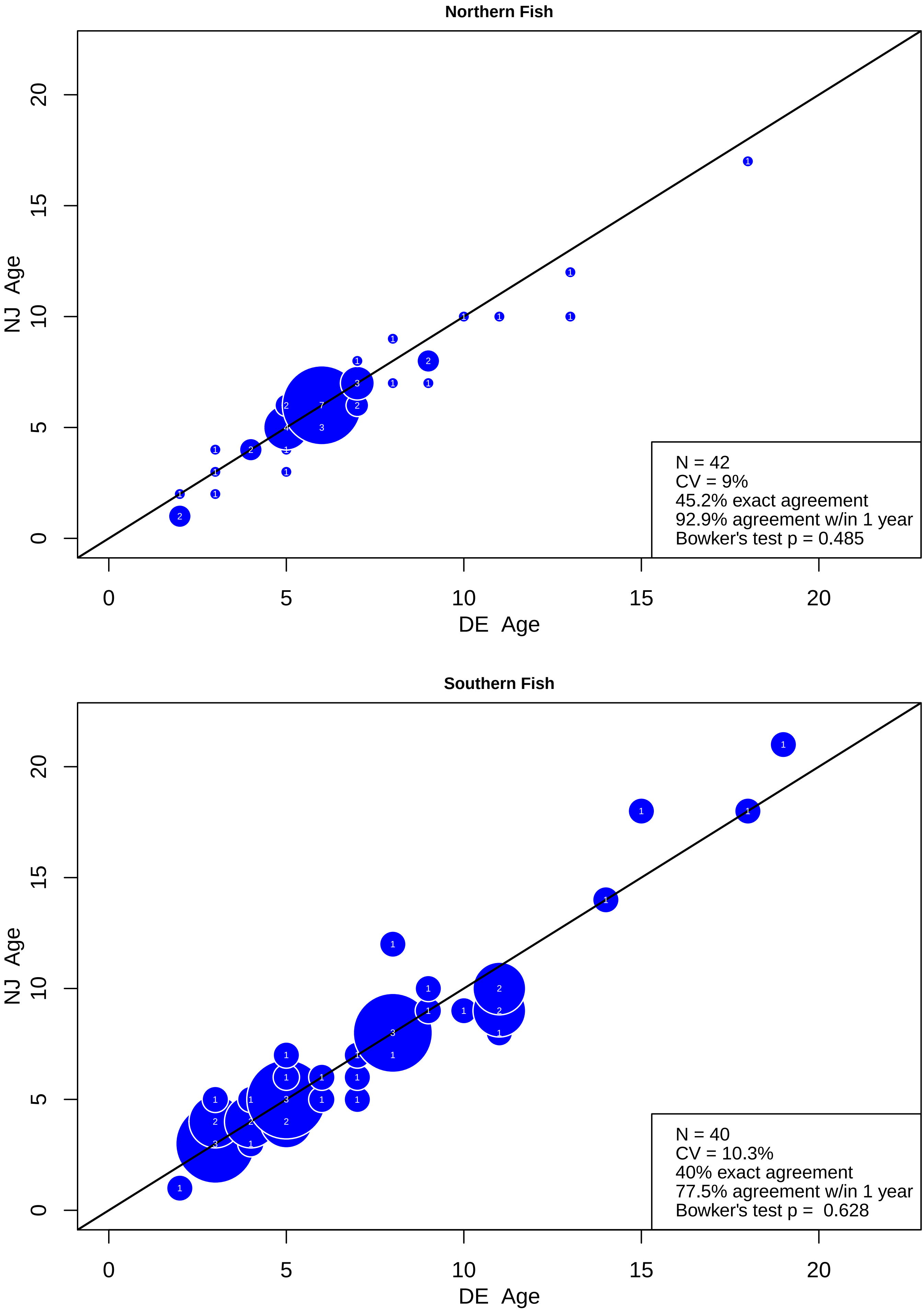


Figure 67: NJ vs. DE bias plots of operculum ages by region of sample origin.

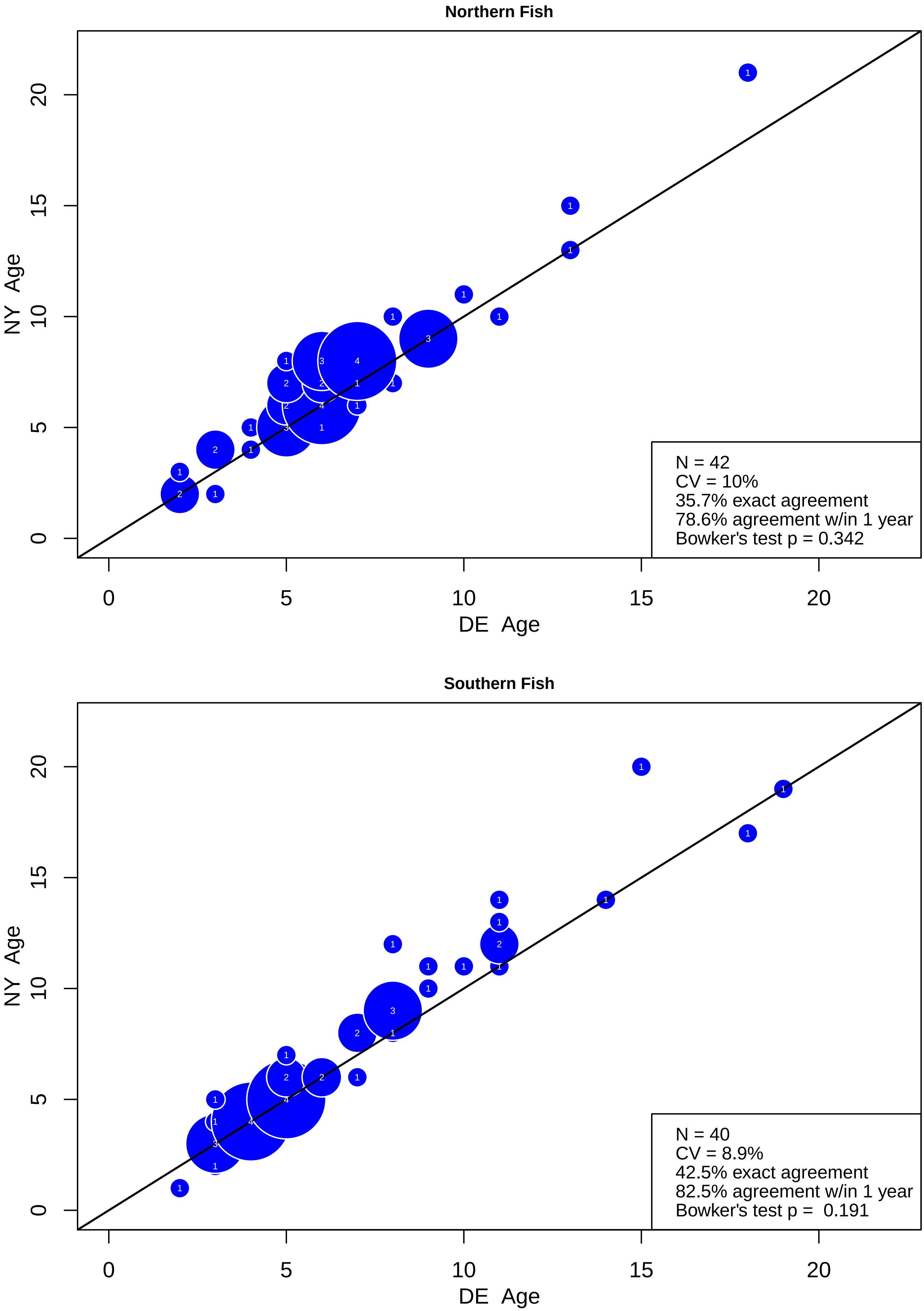


Figure 68: NY vs. DE bias plots of operculum ages by region of sample origin.

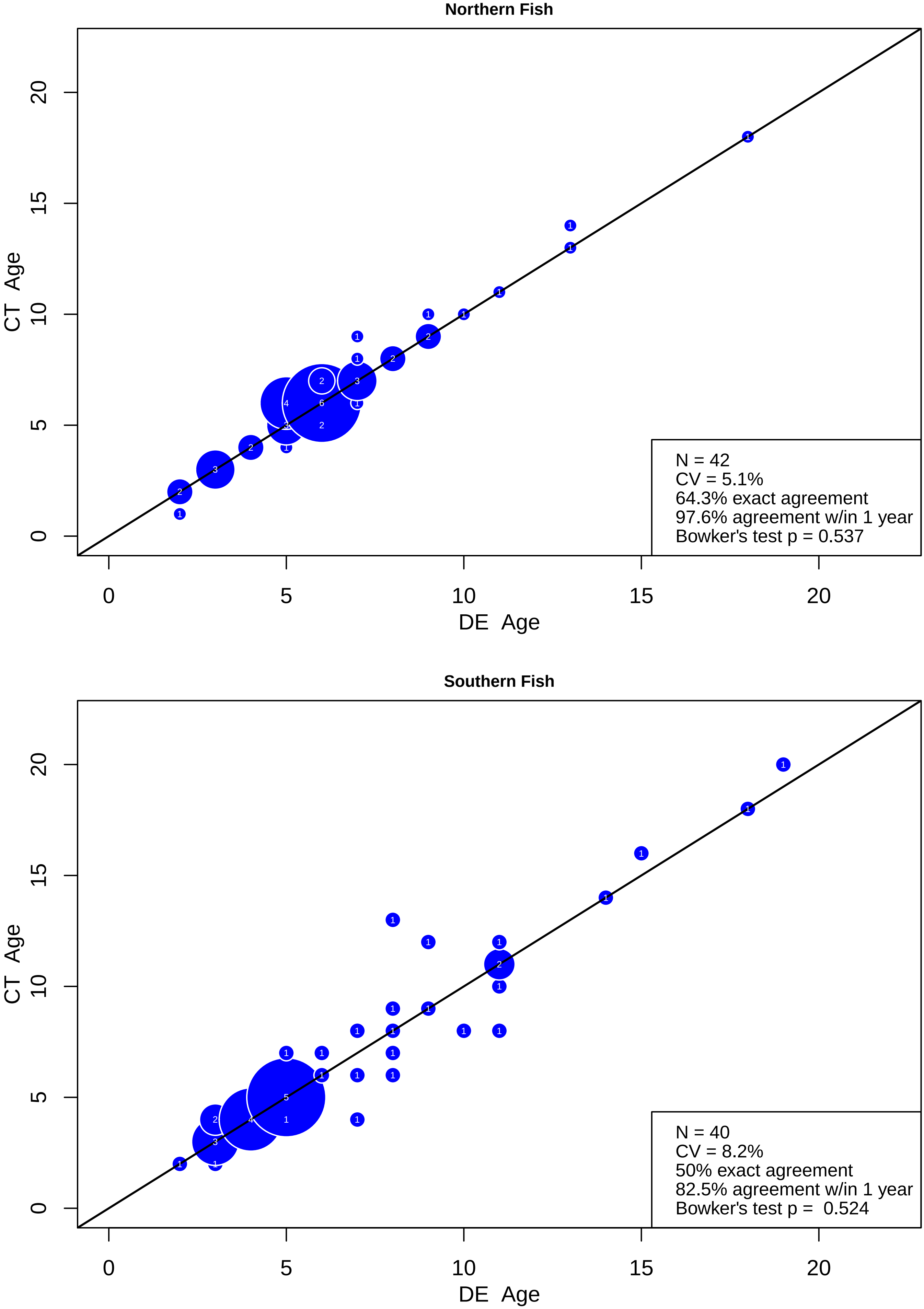
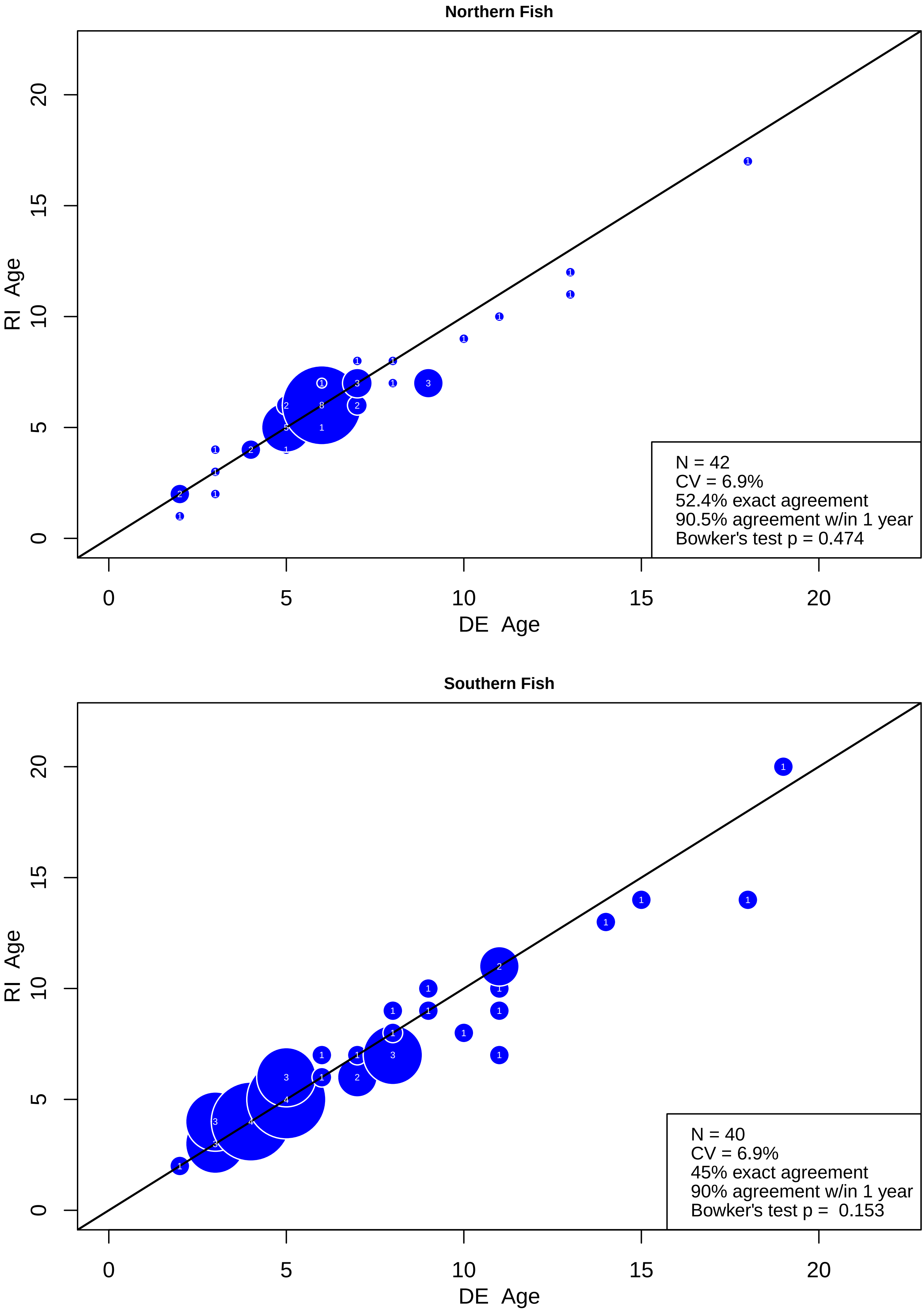


Figure 69: CT vs. DE bias plots of operculum ages by region of sample origin.



Northern Fish

Southern Fish

Figure 70: RI vs. DE bias plots of operculum ages by region of sample origin.

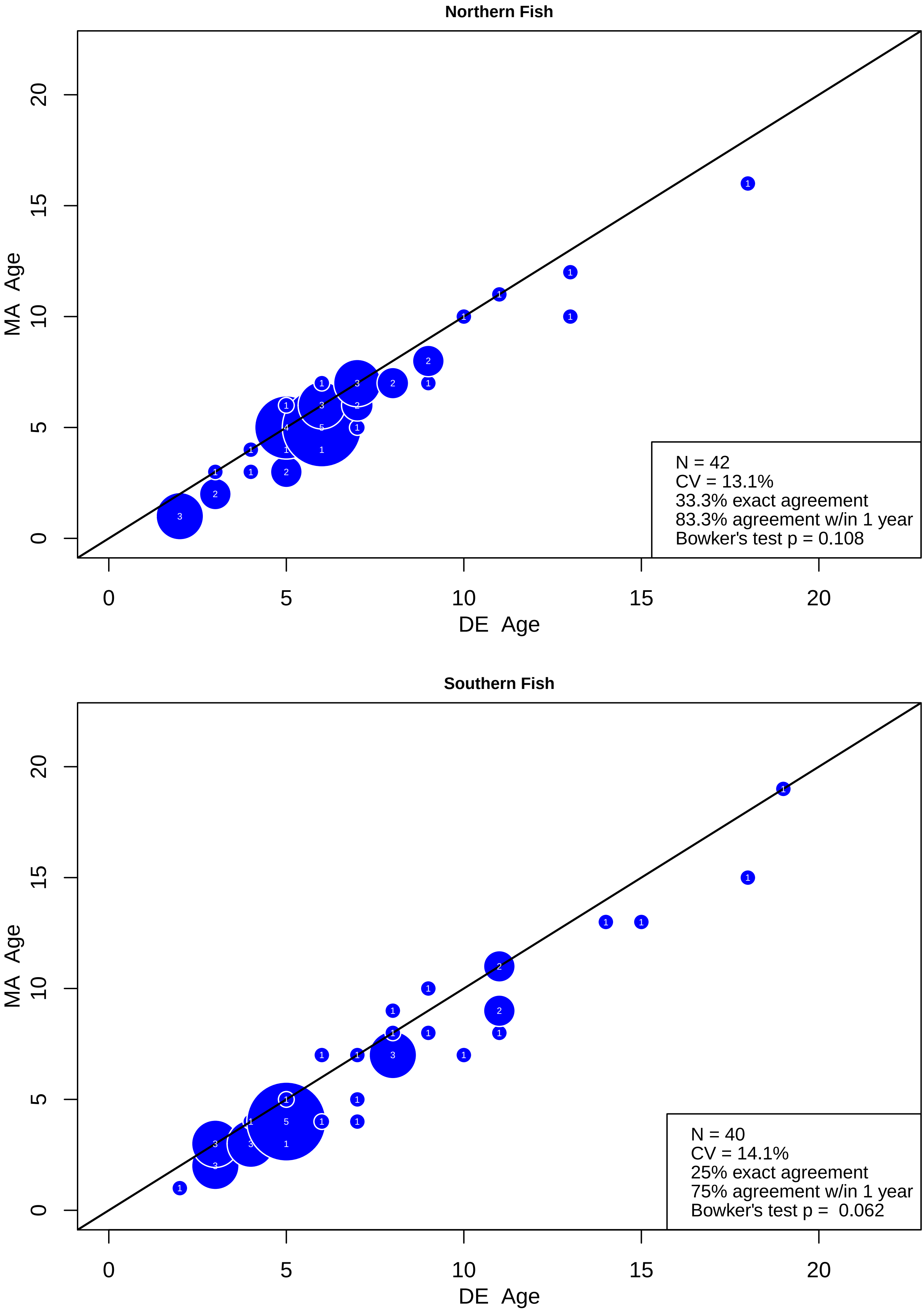


Figure 71: MA vs. DE bias plots of operculum ages by region of sample origin.

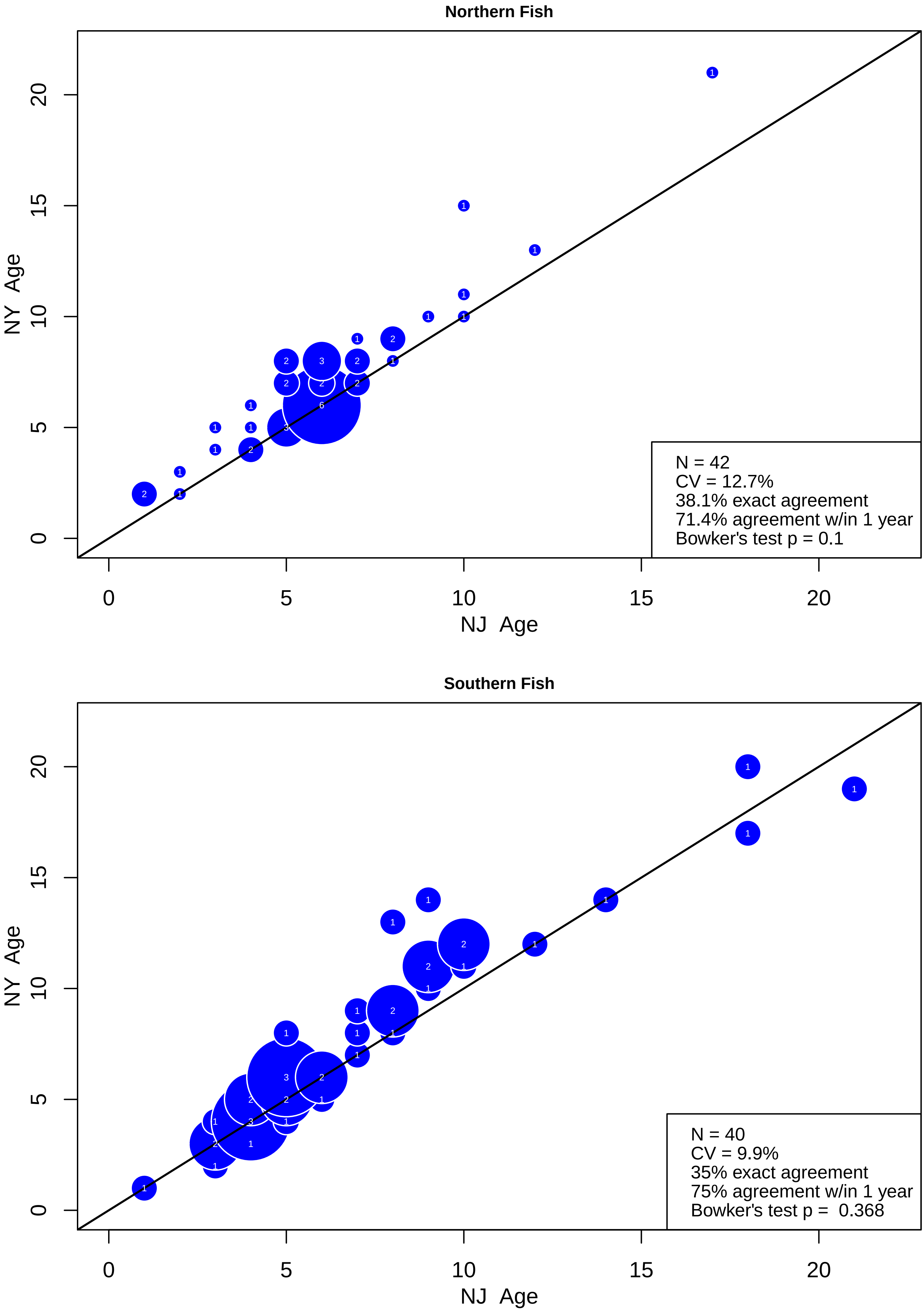


Figure 72: NY vs. NJ bias plots of operculum ages by region of sample origin.

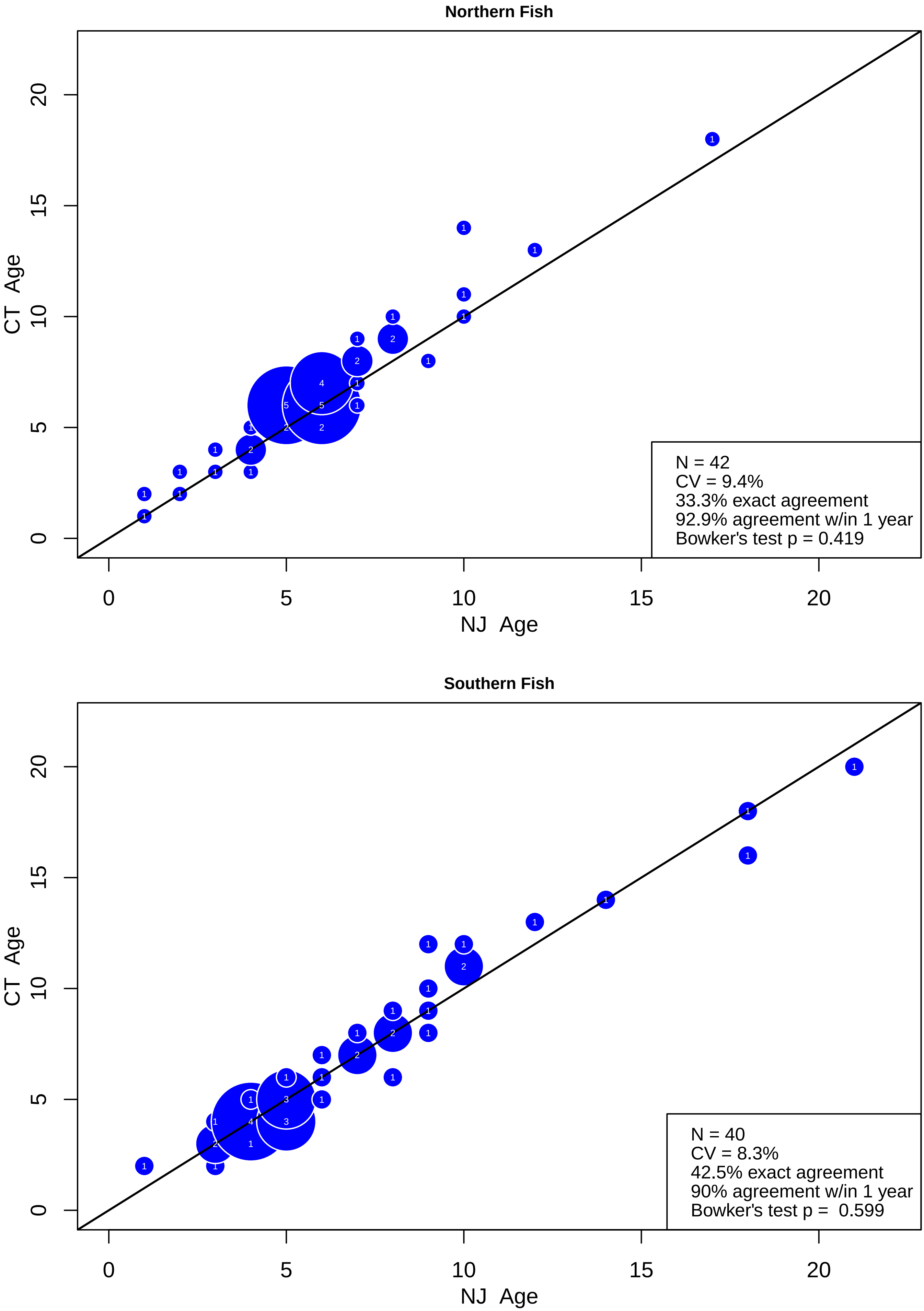


Figure 73: CT vs. NJ bias plots of operculum ages by region of sample origin.

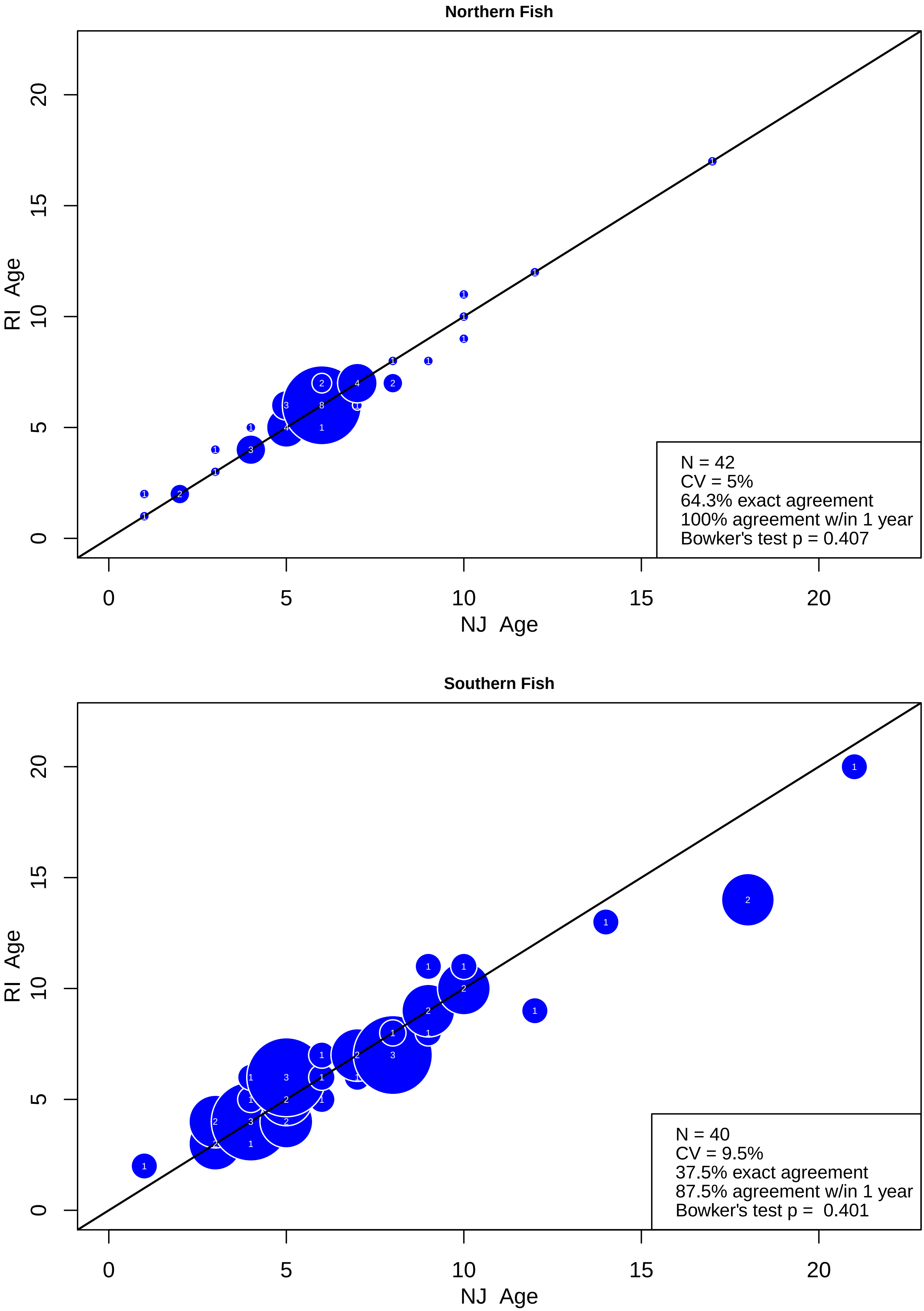


Figure 74: RI vs. NJ bias plots of operculum ages by region of sample origin.

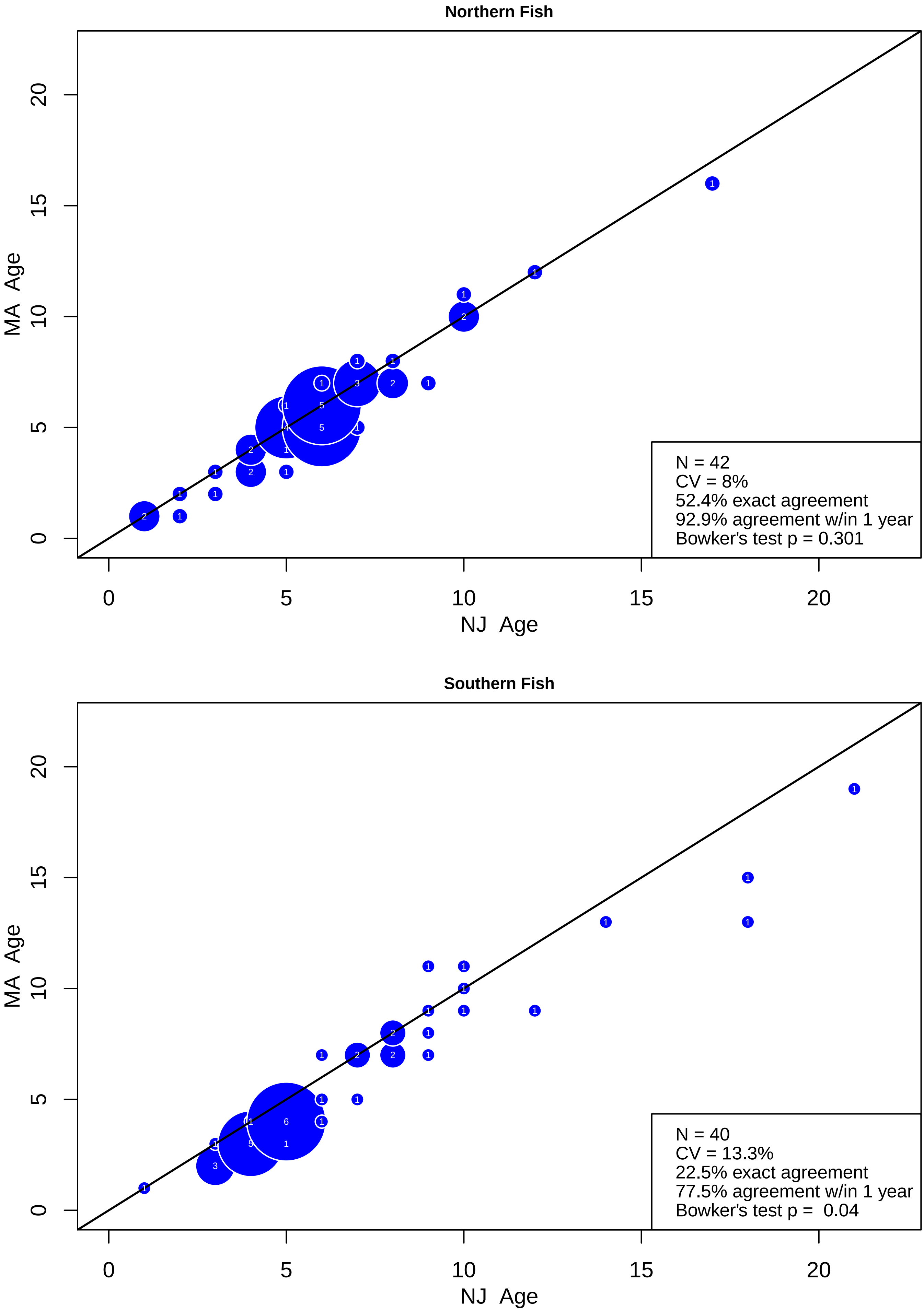
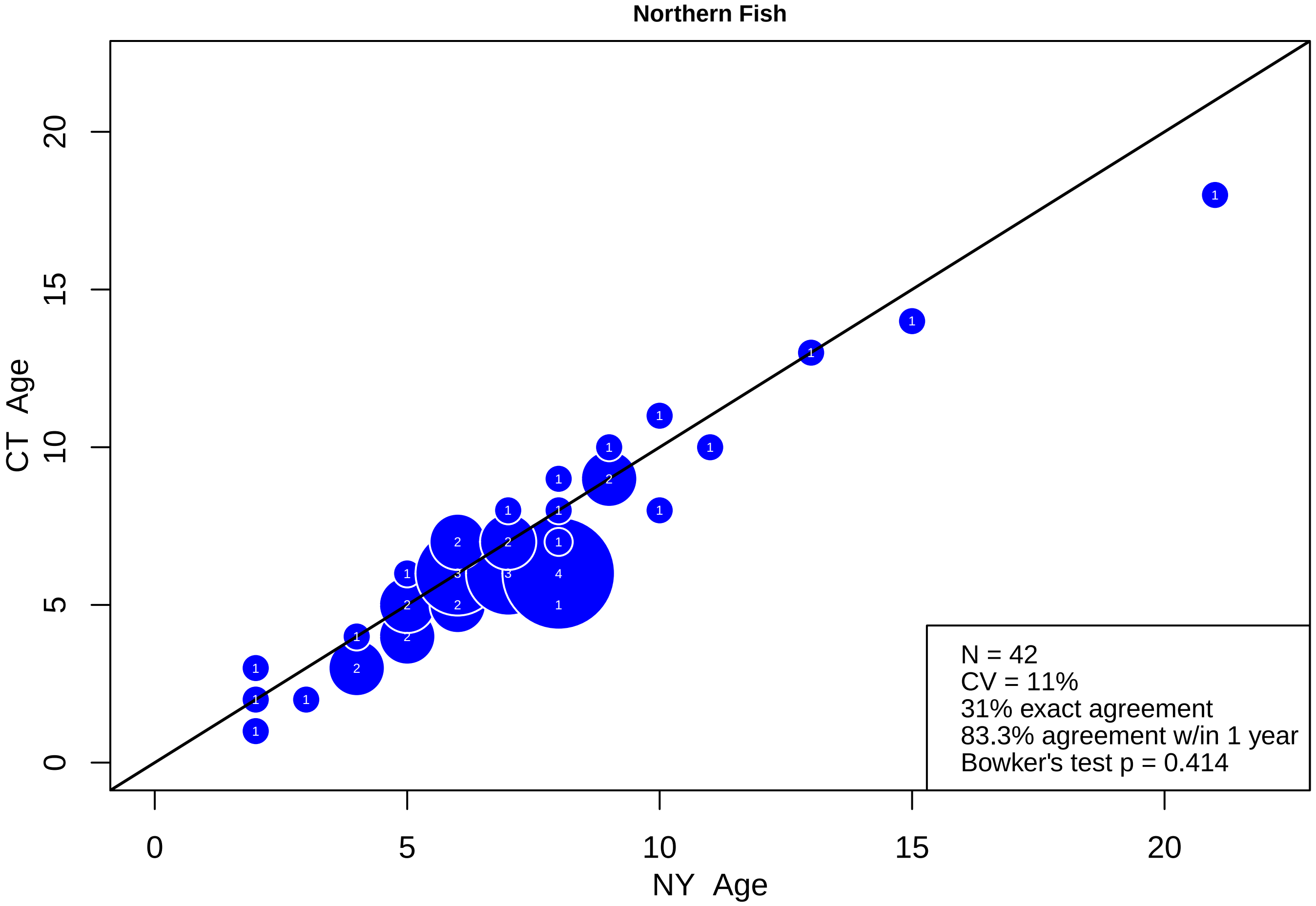


Figure 75: MA vs. NJ bias plots of operculum ages by region of sample origin.



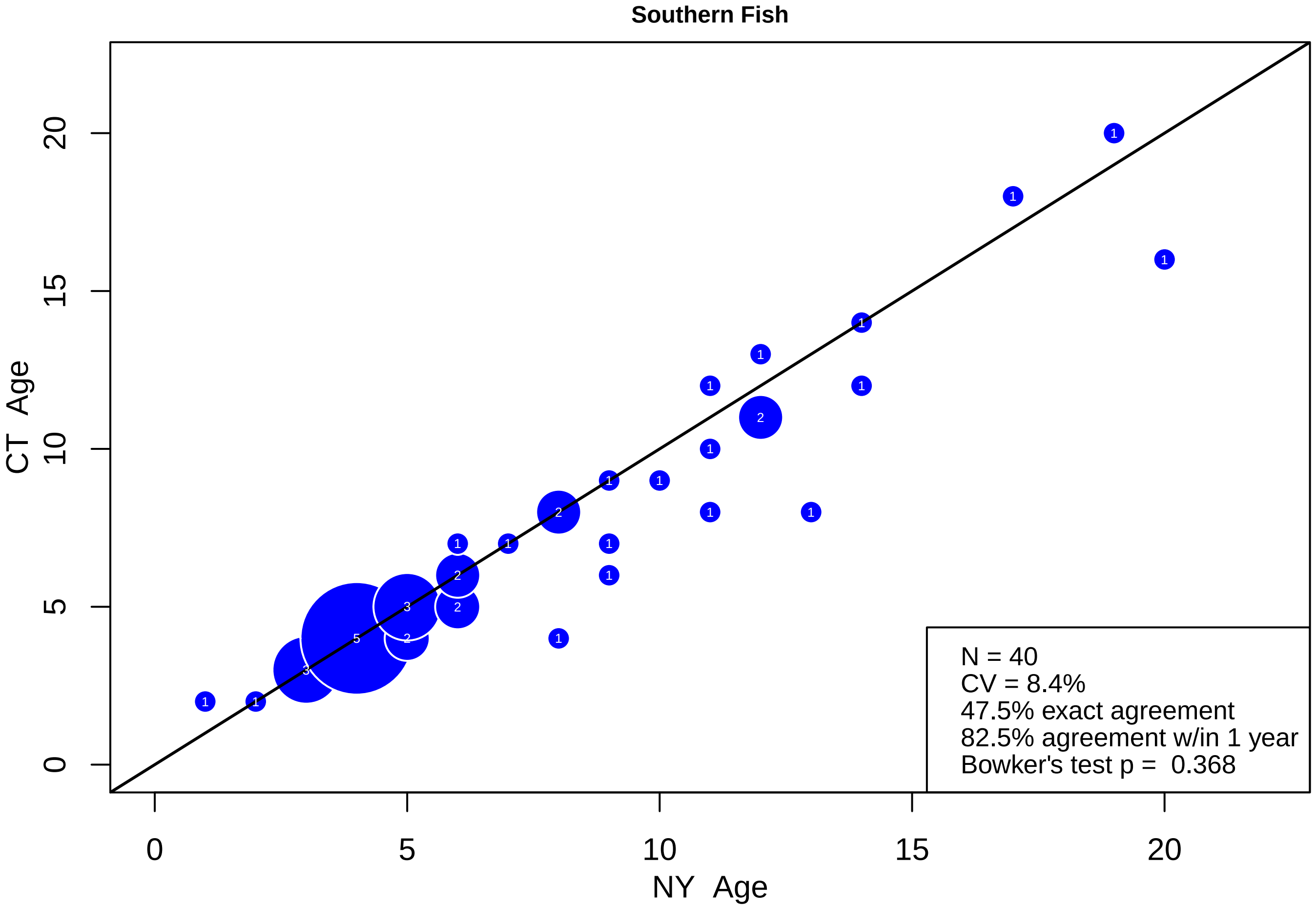


Figure 76: CT vs. NY bias plots of operculum ages by region of sample origin.

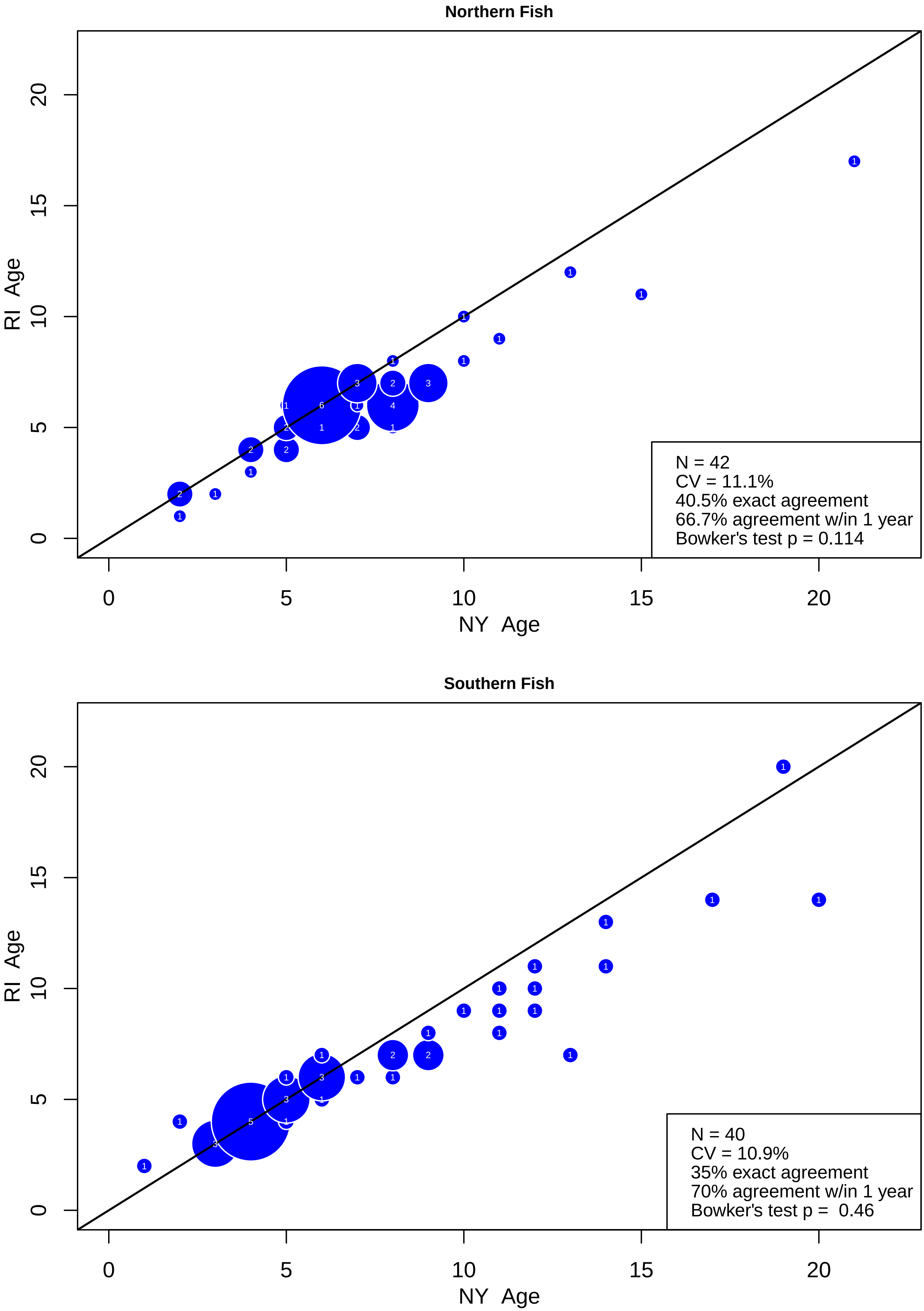
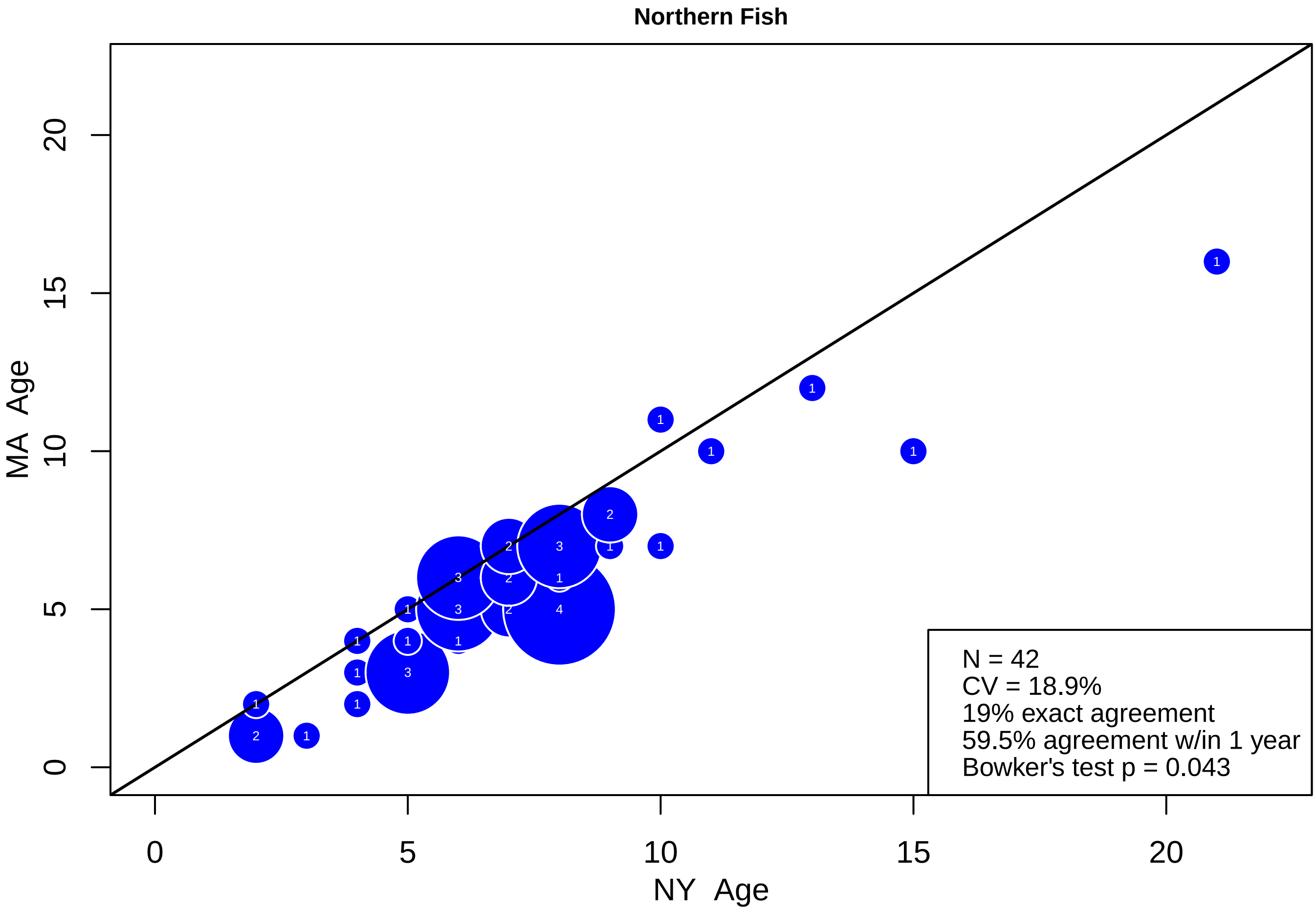
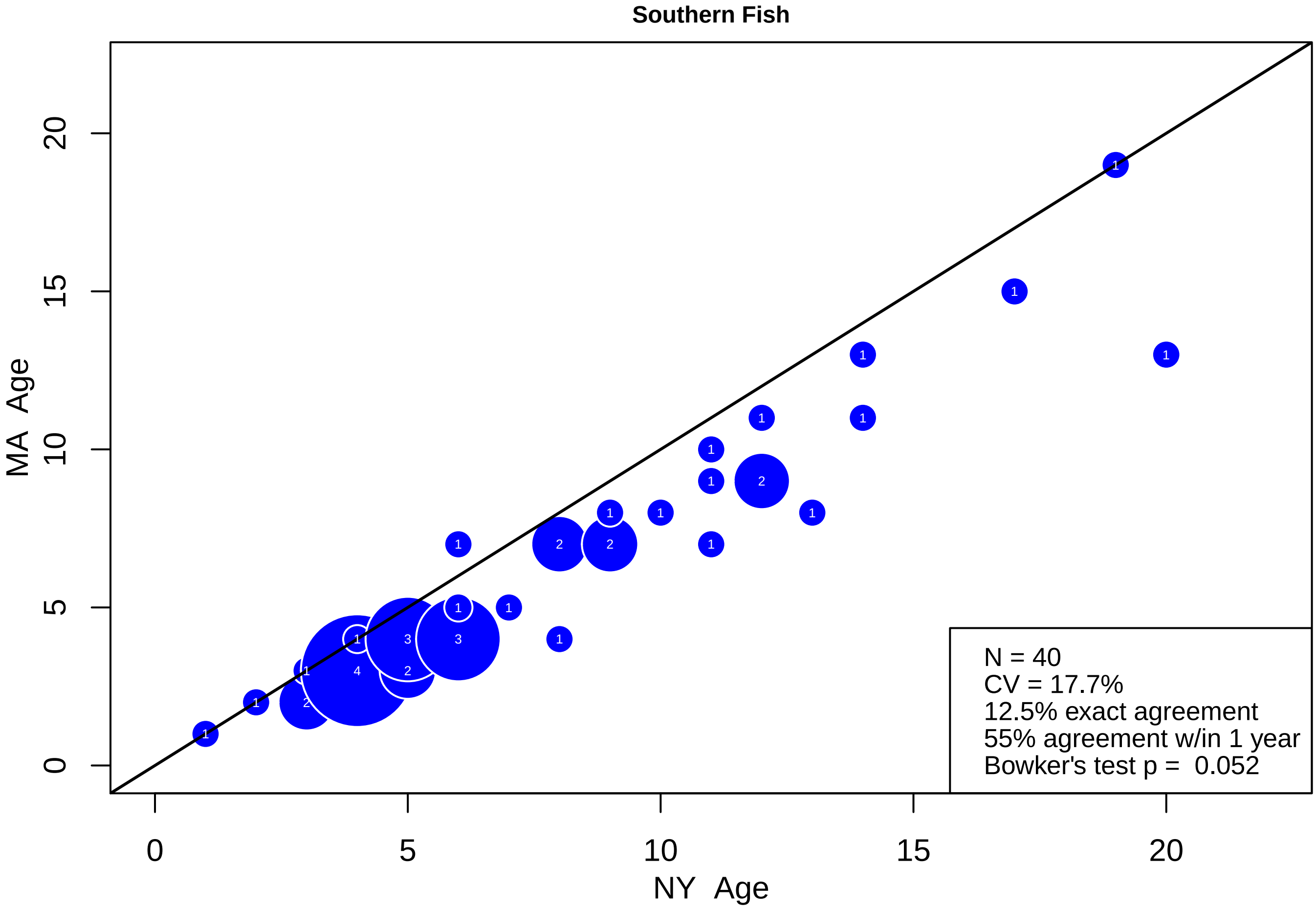


Figure 77: RI vs. NY bias plots of operculum ages by region of sample origin.



Northern Fish



Southern Fish

Figure 78: MA vs. NY bias plots of operculum ages by region of sample origin.

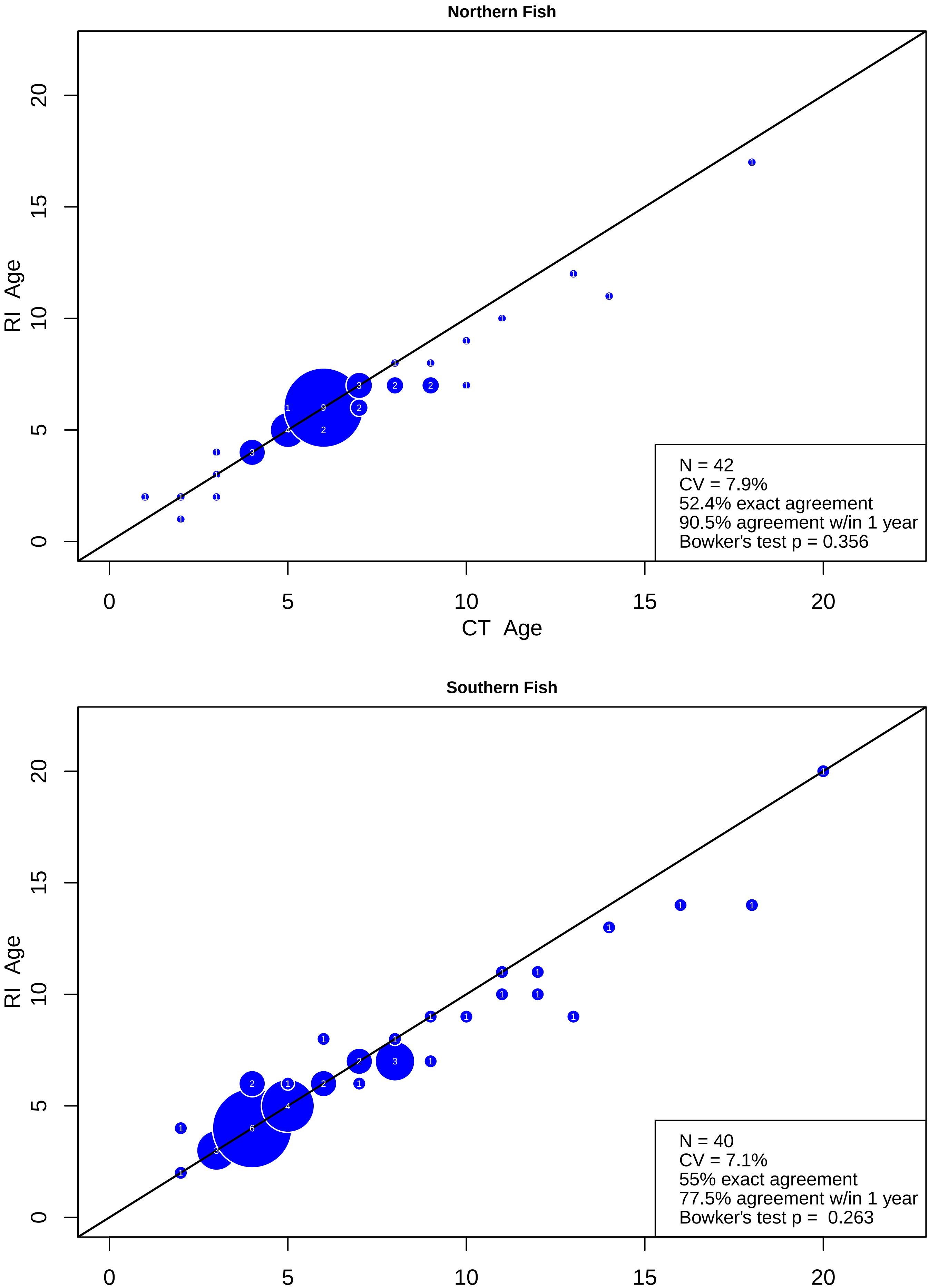


Figure 79: RI vs. CT bias plots of operculum ages by region of sample origin.

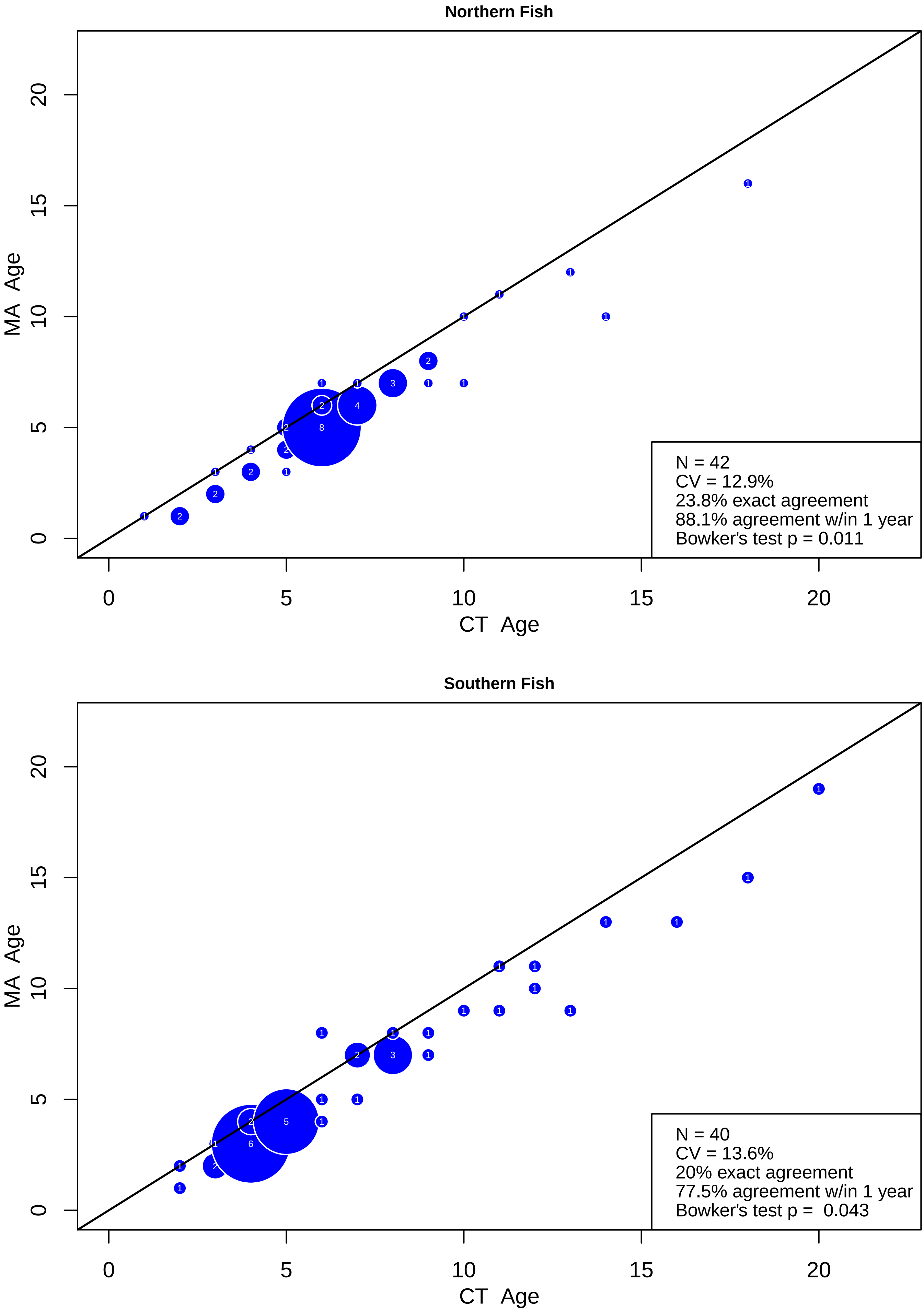


Figure 80: MA vs. CT bias plots of operculum ages by region of sample origin.

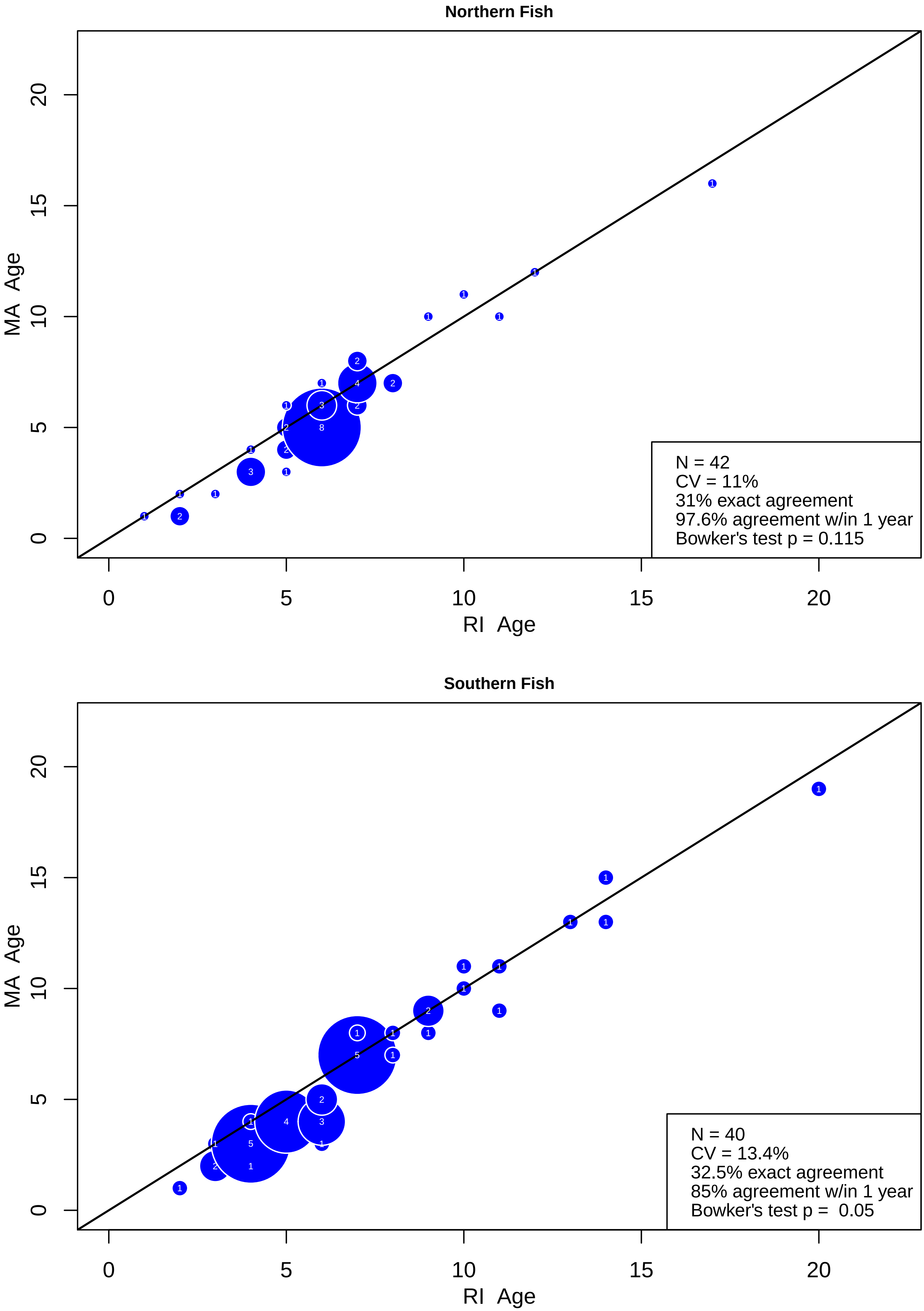


Figure 81: MA vs. RI bias plots of operculum ages by region of sample origin.

Appendix 1: Workshop and Hard Part Exchange Participants

Paul Caruso
Massachusetts Division of Marine Fisheries
1213 Purchase St., 3rd Floor
New Bedford, MA 02740
paul.caruso@state.ma.us

Joe Cimino
Virginia Marine Resources Commission
2600 Washington Ave.
Newport News, VA 23607
joe.cimino@mrc.virginia.gov

James Davies
Hongsheng Liao
Cynthia Jones
Old Dominion University
Center for Quantitative Fisheries Ecology
800 W. 46th St.
Norfolk, VA 23508
jdavies@odu.edu
hliao@odu.edu
cjones@odu.edu

Katie Drew & Chris Vonderweidt
Atlantic States Marine Fisheries
Commission
1050 N. Highland St, Suite 200A-N
Arlington, VA 22201
(703) 842 - 0740
kdrew@asmfc.org
cvonderweidt@asmfc.org

Sandra Dumais (via webinar)
NYSDEC Marine Resources
205 Belle Mead Road
East Setauket, NY. 11733
sadumais@gw.dec.state.ny.us

Scott Elzey
Massachusetts Division of Marine Fisheries
30 Emerson Ave
Gloucester, MA 01930
Scott.elzey@state.ma.us

Garry Glanden
Scott Newlin
Delaware Division of Fish and Wildlife
3002 Bayside Drive
Dover, DE 19901
garry.glanden@state.de.us
scott.newlin@state.de.us

Kurt Gottschall
Connecticut Department of Energy and
Environmental Protection
Marine Fisheries Division
333 Ferry Road
Old Lyme, CT 06371
kurt.gottschall@ct.gov

Jameson Gregg (exchange only)
Virginia Institute of Marine Science
Rt. 1208 Greate Rd
Gloucester Point, VA 23062
jgregg@vims.edu

Nick Marzocca
Anthony Mazzarella
New Jersey Division of Fish and Wildlife
Milepost 51
Rt.9 N
Port Republic N.J. 08241
nick.marzocca@dep.state.nj.us
tony.mazzarella@dep.state.nj.us

Nicole Travisono
Rhode Island DEM Fish & Wildlife
3 Ft. Wetherilll Rd
Jamestown, RI 02835
nicole.travisono@dem.ri.gov

Angel Willey
Maryland Department of Natural Resources
301 Marine Academy Dr.
Stevensville, MD 21666
abolinger@dnr.state.md.us