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AGE-LENGTH KEYS AVAILABILITY FOR ATLANTIC BLUEFIN TUNA CAPTURED IN THE EASTERN MANAGEMENT AREA.

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SUMMARY

This paper analyzes the available direct ageing information in the last decade from Atlantic bluefin tuna caught in the eastern management area. To investigate differences among ALKs, a standard Von Bertalanffy growth function (VB) was fit to length at age data for each stratum. A deficient convergence of VB fitting to the asymptotic length due to the scarcity of old specimens was found for all available ALKs. After these analyses some records were identified as outliers (reading methodological issues) and removed from the data base.

KEYWORDS

Age estimates, age-length key, Thunnus thynnus.

1. Introduction

The stocks assessments used to provide management advice for Atlantic bluefin tuna (*Thunnus thynnus*, ABFT) rely on age-structured population analysis. The method applied for transforming length structured data to age structured data is age slicing using a deterministic growth model (ICCAT, 2013). In recent years the "bluefin tuna Species Group" from the International Commission for the Conservation of Atlantic Tunas (ICCAT) is trying to move to an alternative approach to estimate age composition using age-length keys (ALKs) (ICCAT, 2013b; 2015). Through contributions from the ICCAT research project for bluefin tuna (GBYP) and national research projects there has been a great progress in the standardization of the methodology of age interpretation from ABFT calcified structures (otoliths and spiny rays) addressing consistency between readings within and between laboratories (Rodriguez-Marin et al., 2007; Secor et al., 2014; Busawon et al., 2015). Applying this background this paper analyzes the available direct ageing information in the last decade from ABFT caught in the eastern management area.

2. Material and methods

We have analyzed 3 sets of data comprising nearly 4000 readings from ABFT otoliths and fin spines. The first set of data comes from the IEO (Instituto Español de Oceanografía, Spain) with 47% of the records (otoliths and spines), the second one from GBYP (ICCAT) with 27% (otoliths and spines) and finally from MSDEC-FCD (Department of Fisheries and Aquaculture, Malta) with 26% (only spines). The IEO and GBYP readings come from calcified structures prepared and interpreted following the standardized methodology described in Busawon et al. (2014) for otoliths and Luque et al. (2014) for fin spines, final age was adjusted to account for the date of capture and the timing of bands formation throughout the year following Luque et al. (2014) for spines and ICCAT 2015 adopted criterion for otoliths (Rodriguez-Marin et al., 2016). The Maltese aged spines do not fully

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follow the standardized age interpretation methodology since no edge type was recorded neither age was adjusted to account for the date of harvesting; therefore it was treated as a separated data set.

We merged ageing data with stock identification analysis from the "Biological Studies Project" (GBYP) for obtaining stock ALKs. We have considered four methods for stock assignation: Capture Location (CL), where all ABFT caught in the Mediterranean have been assigned to East origin, Stable Isotope analysis (SI), Genetic analysis (G), and otolith shape analysis (OS). The criterion for samples analyzed with multiple methods was as follows: CL > SI > G >OS. East stock identification percent values over 70% for SI, G or OS have been considered as East origin and lover tan 30 % have been considered as West origin (Fraile et al., 2014; Rooker et al., 2014). In between, no stock identification.

Aged individuals ranged from 22 to 284 cm straight fork length (SFL) cm, with nearly 1600 samples coming from the north east Atlantic and 2400 from the Mediterranean (**Table 1**). Any of the years had adequate sampling coverage throughout the size range (at least 10 samples per 10 cm bin), except for 2011. In order to be sure to have a good representation of, first, the whole length range and secondly geographic location, month, etc., we decided to pool samples to construct several ALKs using the following strata:

- Catch location: "All East": data from specimens caught east of 45º W (including Mediterranean without Malta); "AtlNE": specimens caught east of 45º W excluding the ones caught in the Mediterranean; and "Med": specimens caught in the Mediterranean (excluding Maltese data).
- Stock identification: East. 1575 records were "identified" as East origin and 37 as West origin.
- Multi-year periods: 2005-2009 and 2010-2014. We also analyze the year 2011 alone.
- The combination of the previous strata.
- Maltese data set.

To investigate differences among ALKs, a standard Von Bertalanffy growth function (Von Bertalanffy, 1938) was fitted to length at age data for each stratum ALK:

$$SFL_t = SFL_\infty (1- e^{-k(t-t0)})$$

where: SFLt = straight fork length at age class t (cm), SFL∞ = predicted asymptotic straight fork length (cm), k = instantaneous growth coefficient (year-1), t = age (year), t0 = point at which the Von Bertalanffy curve intersects the x-axis (year).

Von Bertalanffy (VB) parameters and their standard error were estimated using the FSA r-package (Ver. 0.6.24) (Ogle, 2016). Residuals from each VB fit were plotted to check for any unexpected patterns.

3. Results *and D*iscussion.

Von Bertalanffy growth curve parameters from the selected strata ALKs showed in general high values of the asymptotic length, and consequently low values of k, compared to the values of both parameters from previous studies (reviewed in Luque et al., 2014) (**Table 2**). Asymptotic lengths tend to be higher for ALKs that only include ages up to 14 years old. These results from fitting observed length to age data illustrates the sensitivity of parameter estimation due to the lack of fish samples of specimens older than 14 years. The conventional VB growth model can produce unrealistic estimates of growth parameters, especially when there are few samples of very large fish (Pauly, 1979).

Despite the deficient convergence of VB fitting to the asymptotic length due to the scarcity of old specimens, the fit of well-sampled ages do not have this bias. Therefore VB fits by stratum-ALK for well represented ages were compared to search for differences among them (**Figure 1**) and the residual plots of some fits (**Figure 2**). VB growth curves fit to the several ALKs overlapped except for Maltese and IEO data from 2005 to 2009 for ages older than 9 years. After these analyses we have decided not using some records because of unreliability in the readings: Maltese records which show a systematic difference of one year in all ages compared with the rest of the ALKs (reading methodological issues) and IEO data from 2005 to 2009 for older specimens (lack of confidence in the readings due to inexperience with old specimens).

Figures comparing ALKs also included the ICCAT currently adopted growth function for the East Atlantic and Mediterranean stock (Cort, 1991) (**Figure 1**). Overall, differences were found between the adopted growth curve for the East stock and present ALKs from age 6. These differences are more evident with Atlantic ALKs, where our results showed a greater curvature at the ages 7 to 11 than those in Cort (1991).

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Table 1. Number of samples by year and ocean/sea.

East Atlantic without the Mediterranean											
SFLcm/Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
20-30											
30-40											
40-50											
50-60	5	1					15				21
60-70	45	30	4		1		10	5			95
70-80	41	6	15	13	2	2	11				90
80-90	11		23	15	22	43	59				173
90-100	38	3	1	10	12	26	5				95
100-110	30	2	6		21	5	23	9			96
110-120	15	6	6	8	17	6	17	10			85
120-130	2	1	4	11	6	3	4	11			42
130-140	3	1		7	3		14	3			31
140-150	4	3	1		6	1	17	1			33
150-160	3	20		1	9	3	12				48
160-170	1	9	7	16	6	18	3	8			68
170-180	4	5	17	8	3	15	12	6			70
180-190	8	3	8	8	8	9	32	7			83
190-200	1	2	3	8	6	15	29	11			75
200-210	11			4		23	33	38	2		111
210-220	28	1	1	6		19	33	33	7		128
220-230	35			4		6	27	12	1		85
230-240	43			4		4	26	8	7		92
240-250	16			3		1	5	7	4		36
250-260	7			1		5	4	1			18
260-270	2			1				2			5
270-280	1			1			1				3
280-290								1			1
290-300											
Total	354	93	96	129	122	204	392	173	21	0	1584

Mediterranean											
SFLcm/Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
20-30						1	10				11
30-40	25				8	29	10				72
40-50	3		3				6				12
50-60	3		20			3	3				29
60-70			18	20	1		7				46
70-80	3		1	41			29				74
80-90	5		2	36	3		19	1			66
90-100	3			26	10	3	22	5			69
100-110	3		5	11	4	5	52	2			82
110-120	5	1	4	20	2		138	8			178
120-130	2	1	2	18	10	2	68	18			121
130-140	1	1	2	4	12	8	91	67	7		193
140-150	3		1	1	7	9	73	41	5	3	143
150-160	1	1	1		3	12	56	13	4	8	99
160-170	2	1	3	1	2	34	39	15	1	7	105
170-180	4	3	3	2	1	39	30	5		3	90
180-190	9	6	10	7		31	23	3	2	1	92
190-200	13	10	11	22	6	11	18	3	2	3	99
200-210	16	20	8	18	9	15	21	7	6	6	126
210-220	43	17	5	14	2	14	43	14	13	13	178
220-230	34	26	7	7	8	35	37	16	23	30	223
230-240	12	24	5	8	14	17	27	15	8	31	161
240-250	3	1		3	8	15	12	17	1	9	69
250-260				2	3	3	6	7		5	26
260-270					2	4	6	3			15
270-280						1		2			3
280-290							2				2
290-300											
Total	193	112	111	261	115	291	848	262	72	119	2384

Table 2. Estimates of the von Bertalanffy growth parameters and the standard errors (SE).

Aged samples identification	Stratum (ALK)			L_∞		K		t_0	
		N	Age Range	Estimated	SE	Estimated	SE	Estimated	SE
All east	1	2916	0 to 16	390.04	9.44	0.07	0.00	-1.35	0.05
AtlNE	2	1584	1 to 14	329.32	7.22	0.09	0.00	-1.09	0.07
Med	3	1332	0 to 15	499.98	28.25	0.05	0.00	-1.54	0.08
East stock id.	4	1575	0 to 15	407.60	14.86	0.06	0.00	-1.34	0.07
East stock id. 2005-2009	5	514	0 to 12	543.08	45.83	0.05	0.01	-1.54	0.09
East stock id. 2010-2014	6	1061	0 to 15	391.95	17.05	0.07	0.00	-1.26	0.11
AtlNE 2005-2009	7	794	1 to 13	521.06	33.93	0.05	0.00	-1.61	0.09
AtlNE 2010-2014	8	790	1 to 14	285.87	6.55	0.12	0.01	-0.85	0.10
Med 2005-2009	9	514	0 to 12	543.08	45.83	0.05	0.01	-1.54	0.09
Med 2010-2014	10	818	0 to 15	476.66	33.57	0.05	0.01	-1.48	0.12
2005-2009	11	1308	0 to 13	521.25	25.60	0.05	0.00	-1.56	0.06
2010-2014	12	1608	0 to 16	361.84	10.98	0.08	0.00	-1.28	0.08
Malta	13	1052	3 to 12	316.82	12.68	0.12	0.01	-0.42	0.25
Malta 2005-2009	14	278	3 to 12	249.98	7.64	0.24	0.03	1.01	0.39
Malta 2010-2014	15	774	3 to 12	389.15	30.52	0.08	0.01	-1.19	0.34
2011	16	1240	0 to 16	398.36	18.50	0.07	0.01	-1.29	0.11

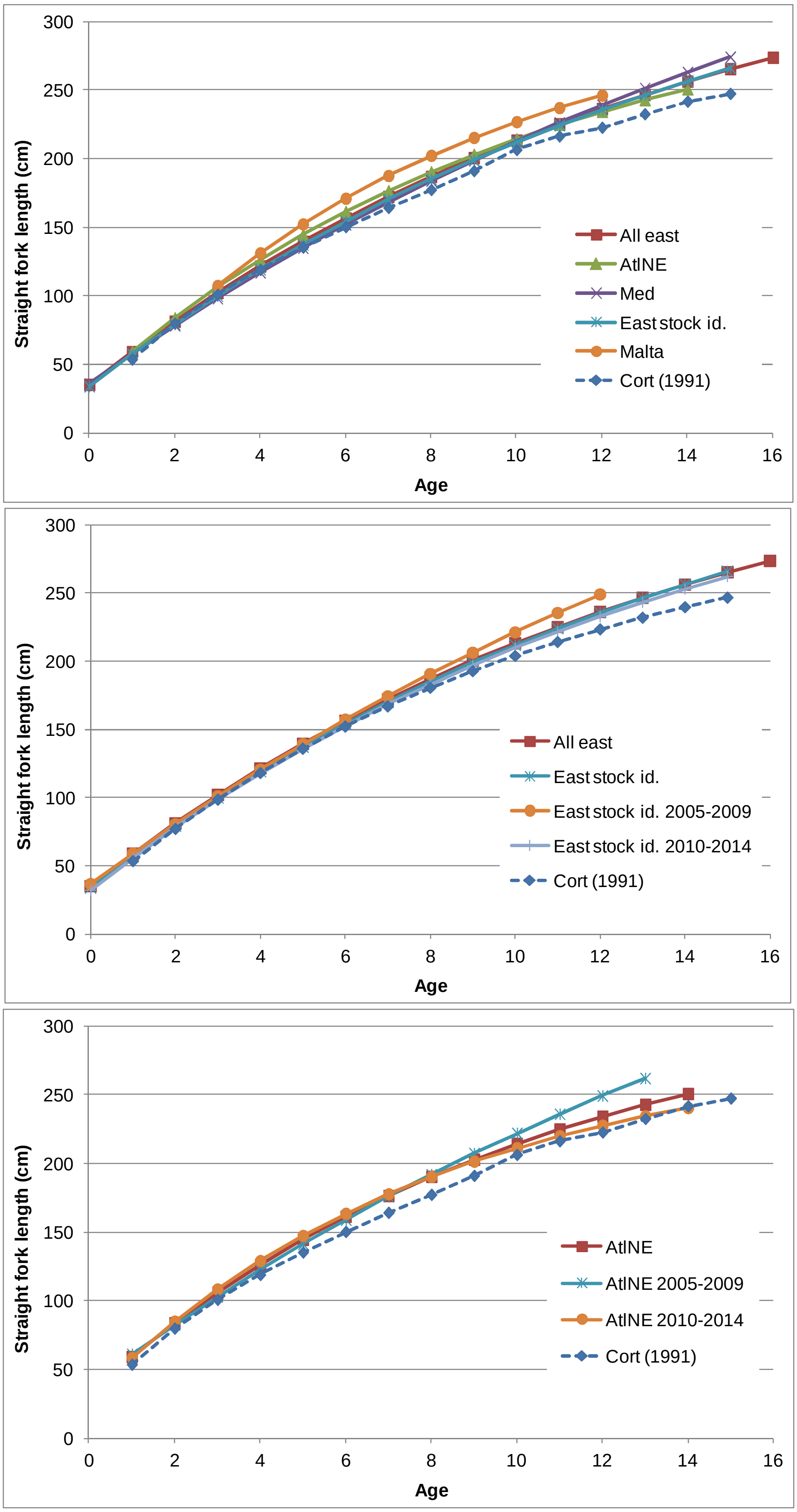
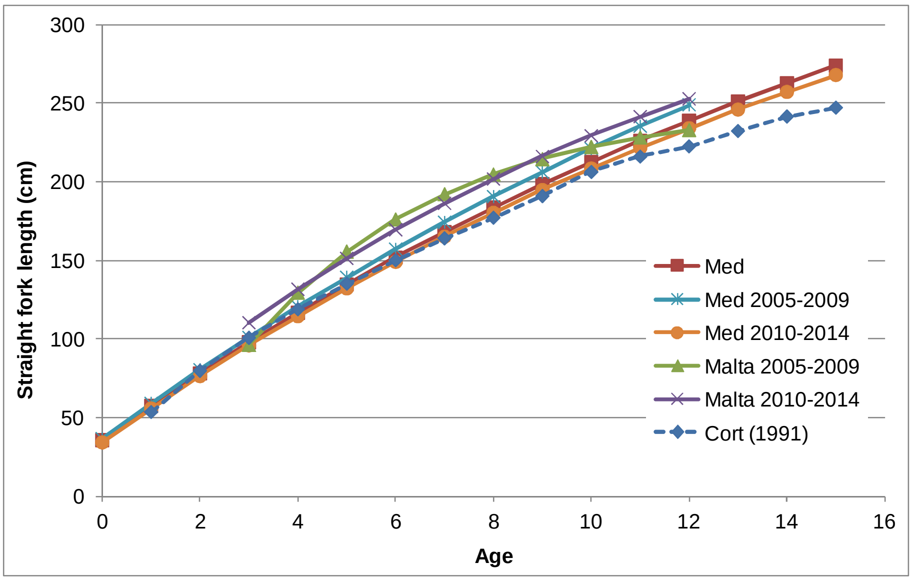


Figure 1. Von Bertalanffy growth model curve fitted to observed length at age data from calcified structures readings from several strata (strata definition in main text).



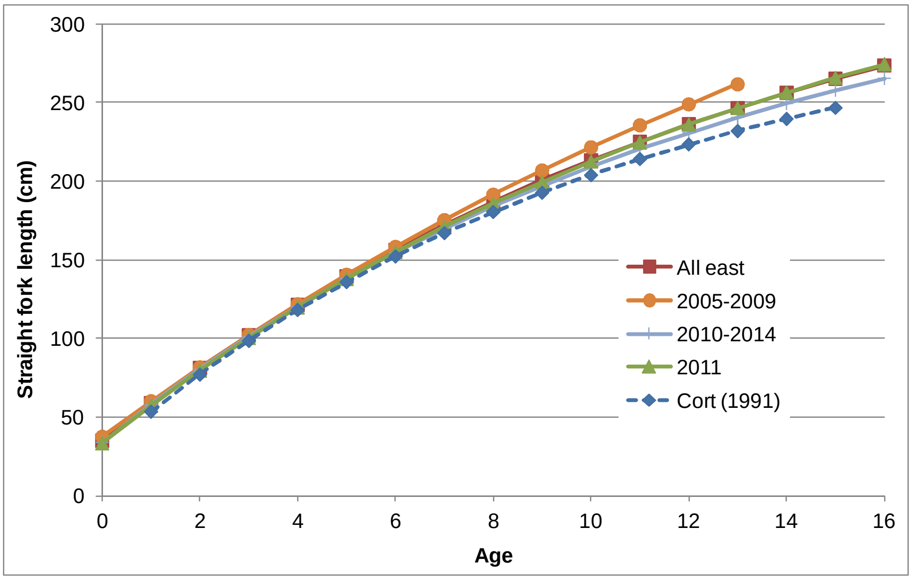


Figure 1cont. Von Bertalanffy growth model curve fitted to observed length at age data from calcified structures readings from several strata (strata definition in main text).

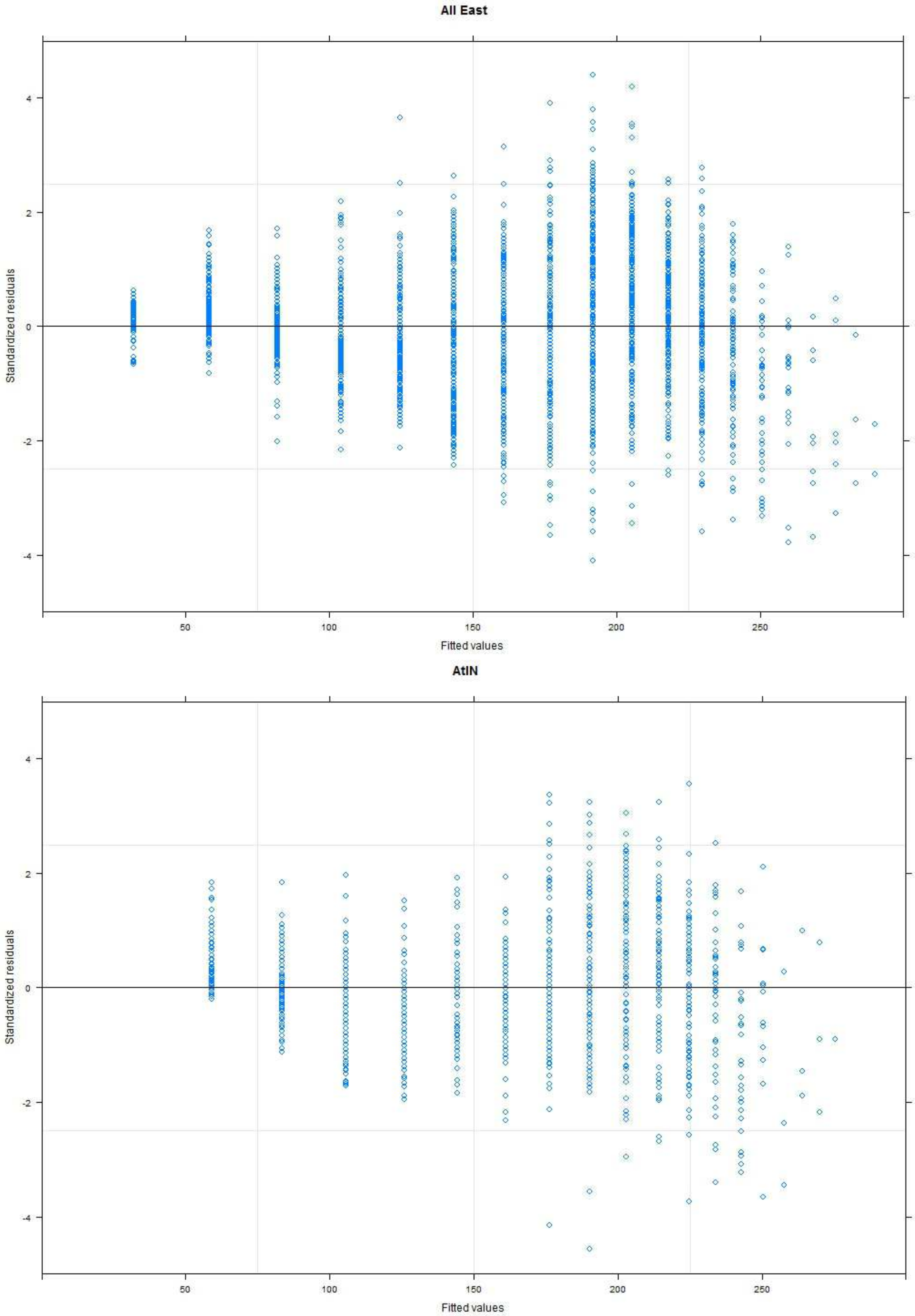


Figure 2. Residuals from different strata von Bertalanffy fits (strata definition in main text).

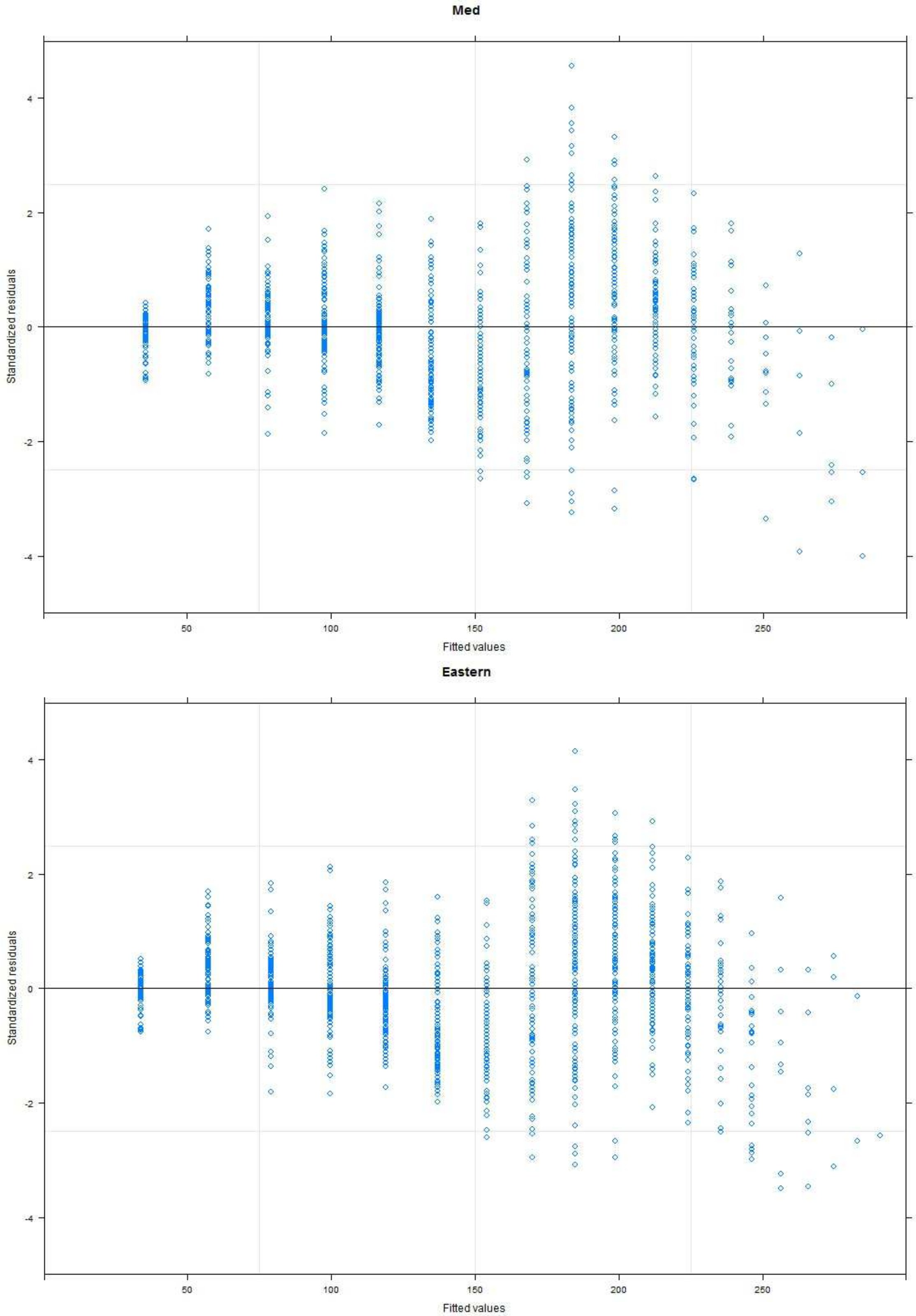


Figure 2 cont. Residuals from different strata von Bertalanffy fits (strata definition in main text).

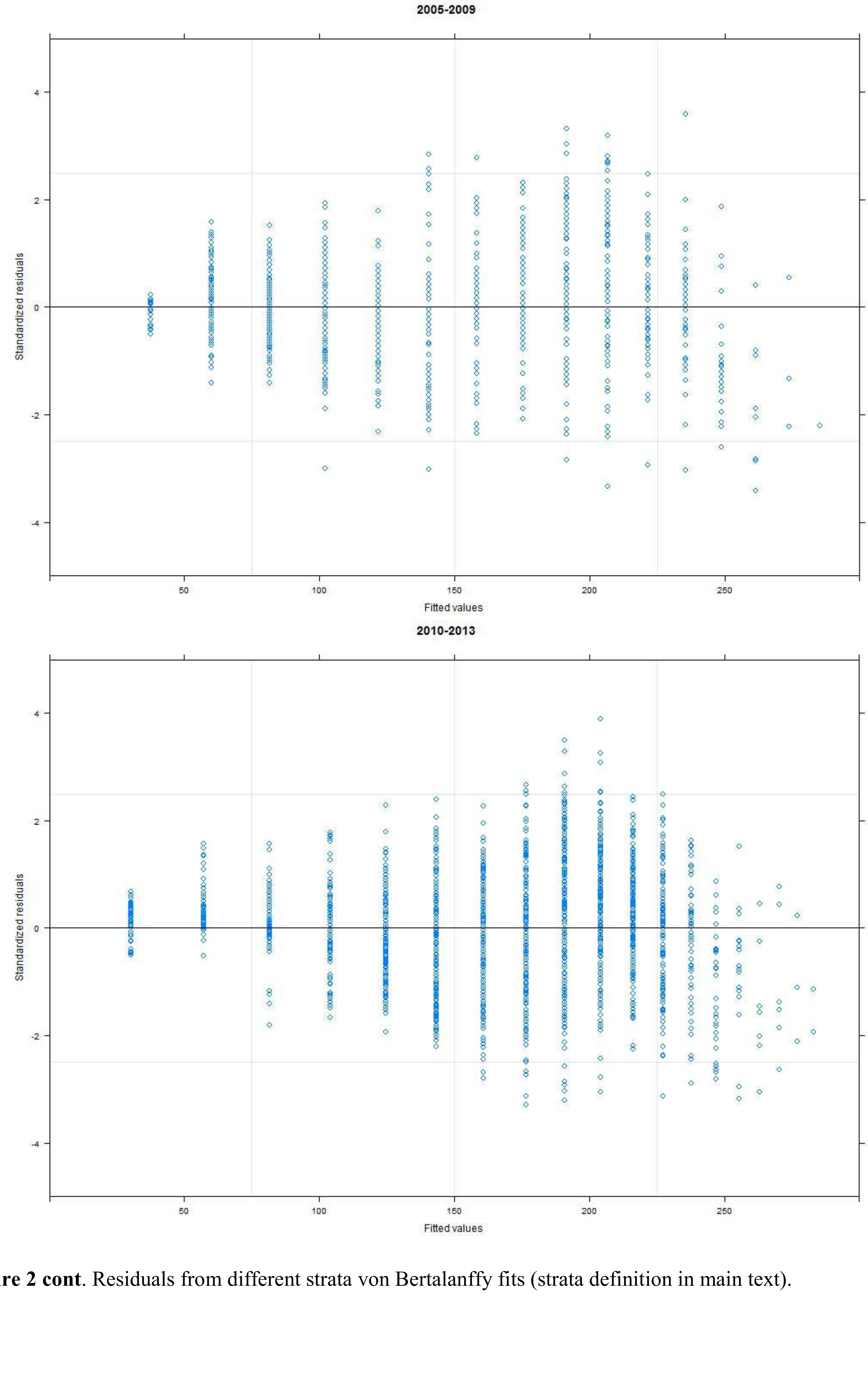


Figure 2 cont. Residuals from different strata von Bertalanffy fits (strata definition in main text).