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SEDAR98-DW-13

25 November 2024

Please cite this document as:

Ailloud, Lisa E. 2024. Gulf of Mexico red snapper (*Lutjanus campechanus*) smooth age length keys. SEDAR98-DW-13. SEDAR, North Charleston, SC. 127 pp.

Gulf of Mexico Red Snapper (*Lutjanus campechanus*) Smooth Age Length Keys

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November 2024

Introduction

Region (West/Central/East) and year (1996-2023) specific smooth age-length keys (Stari et al. 2010) were constructed using red snapper samples collected from the Gulf of Mexico from 1996 to 2023. In SEDAR 52 (SEDAR 2018), region-specific (East/West) age-length keys (ALKs) were constructed to convert observed length composition into age composition for the combined ROV reef survey (2005-2016), SEAMAP reef fish video survey (2008-2016), commercial discards from the commercial observer program for the open and closed seasons (2007-2016) and recreational discards from the headboat observer program for the open season (2005-2016). In generating these ALKs, age data were pooled over multiple years due to data sparsity. However, pooling data from multiple years is not recommended as it can seriously underestimate the variance in estimated proportions at age and result in severe bias (Aanes and Volstad, 2015; Ailloud et al. 2019). The reason for this can be illustrated with a simple example: say you collected age samples over two consecutive years, in the first year the recruitment strength is exceptionally high such that all 10 fish in the 20-30cm length bin are age 0, and in the second year, the recruitment strength is exceptionally low such that all 10 fish in the 20-30cm bin are age 1 (i.e. slow growing fish from the previous year's strong year class are overwhelming the sample such that none of the new recruits appear in the sample). If one was to pool the two years together to build an overall ALK, one would end up with an estimated probability of .5 for age 0 and .5 for age 1 in the 20-30cm bin for both years, thereby obscuring any information on relative year class strength.

Smooth ALKs (Stari et al. 2010) provide a modeling framework for dealing with data gaps that largely removes the need for pooling years. It is not uncommon for certain length bins to be left unsampled. With a classic forward ALK (Fridriksson, 1934), this would result in not being able to allocate numbers-at-age for fish present in that length bin when the key is applied to a more complete length composition dataset, or having to borrow information from neighboring length bins or years. In contrast, the smooth ALK provides an objective way to fill in these gaps. The approach can also accommodate low sample sizes that typically cause classic ALKs to have illogical results, such as situations where a. a single fish is aged in a length bin but its age is not representative of the typical age of fish in that length bin (i.e. there may be younger fish in higher length bins and older fish in lower length bins), or where b. there are no fish of a given age in a given length bin even though that age is observed in lower and higher length bins.

Methods

Data Description

Red snapper age-length pairs were obtained from a variety of sources. Commercial data were obtained from the Trip Interview Program (TIP) and the Gulf States Marine Fisheries Commission's Fisheries Information Network (GulfFIN). Recreational data were obtained from the Marine Recreational Information Program (MRIP, formerly known as MRFSS), Texas Parks and Wildlife Department's Marine Sport-Harvest Monitoring Program (TPWD), the Southeast Region Headboat Survey (SRHS), and GulfFIN. Fishery independent data were obtained from the Fish and Wildlife Research Institute Fishery Independent Monitoring (FWRI-FIM), FWRI Movement Ecology and Reproductive Resilience laboratory (FWRI-MERR), Dauphin Island Sea Lab, Gulf Coast Research Laboratory (GCRL), and Texas A&M Corpus Christi (TAMUCC). Age samples were processed and read by the SEFSC's Panama City Laboratory and Gulf States age and growth laboratories. All tournament samples were removed to avoid introducing bias.

Within each strata (i.e. year and region), data from all gears and sectors combined were used to generate smooth ALKs since differences in size selectivity between gears/sectors does not preclude an ALK developed from one gear being applied to a different gear as long as the fish available to each gear are from the same population (Westrheim and Ricker 1978).

Length bins ranged from 0-102cm FL with 1cm bin widths and age bins ranged from 0 to the plus group. Two plus group scenarios were explored: 10+ years, 20+ years. All age-length pairs available (1980-2023) are shown in Figure 1. ALKs were constructed starting in 1996 due to data limitations in the early years of age data collections. Sample size availability by sector (recreational, commercial, fishery independent) and nominal age distributions are presented in Figure 2, Figure 3 and Figure 4. Age distributions for the main commercial fleets by region are presented in Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, and Figure 10. Age distributions for the main recreational modes by region are presented in Figure 11, Figure 12, Figure 13, Figure 14, Figure 15, Figure 16, Figure 17, Figure 18, and Figure 19.

The Smooth ALK approach

The Smooth ALK approach (Stari et al. 2010) uses Continuation Ratio Logits (CRLs; Dobson 2002) with Generalized Linear Models (GLMs) to derive probabilities of age given length from sparse data.

Let a refer to age classes ($a = 1,2,...,A$) and k to length classes ($k = 1,2,...,K$). The age and length classes need not start at the lowest observed age group or length class and need not be equally wide but they must be consecutive. Suppose in a given stratum (e.g., region and year) N_k fish of length k have been aged and there are n_{ak} fish belonging to age a and length k. Let the distribution of age in length class k be given by $P(k) = \{P(a = 1|k), P(a = 2|k), \dots P(a = A|k)\}$, where $P(a|k)$ is the probability that a fish in length class k belongs to age class a. The likelihood of observing $\{n_{1k}, n_{2k}, \dots n_{Ak}\}$ fish for a single length class is proportional to:

$$L_k = P(a = 1|k)^{n_{1k}} P(a = 2|k)^{n_{2k}} \dots P(a = A|k)^{n_{Ak}}$$
$$= \prod_{a=1}^{A} P\,(a|k)^{n_{ak}}$$

with the overall likelihood L over all length classes being the product of independent multinomials:

$$L = \prod_{k=1}^{K} L_k$$

We then estimate $P(k)$ using CRLs where the likelihood function L is reparameterized such that the product of likelihoods L_a can be estimated separately for each value of a. The probability distributions $P(a|k)$ can then be derived for each a using GLMs that model age as a smooth function of length.

Let $\pi_a(k)$, the conditional probability of a fish being age a given that it is at least that age, equal to :

$$\pi_a(k) = \frac{p_a(k)}{\sum_{i=a}^{A} p_i\,(k)}, a = 1,2, \dots, A-1$$

$$\pi_A(k) = 1 - \sum_{a=1}^{A-1} \pi_a\,(k)$$

we can then rewrite equation (1) as:

$$L_k = \prod_{a=1}^{A-1} \pi_a(k)^{n_{ak}} \big(1 - \pi_a(k)\big)^{N_{ak}}$$

where $N_{ak} = \sum_{i=a+1}^{A} n_{ik}$ for $a = 1, \dots, A-1; k = 1, \dots, K$. And equation (2) as:

$$L = \prod_{a=1}^{A-1} \prod_{k=1}^{K} \{\pi_a(k)^{n_{ak}} \big(1 - \pi_a(k)\big)^{N_{ak}}\}$$

$$L = \prod_{a=1}^{A-1} \lambda_a$$

where λ_a is a product of binomial likelihoods and $\pi_a(k)$ can be estimated as a function of k for each value of a separately using logistic regression :

$$\pi_a(k) = \frac{1}{1 + e^{\alpha_a + \beta_a k}}$$

where α_a and β_a are the logistic regression parameters to be estimated.

Then, following equations (3) and (4), $P(a|k)$ is obtained as:

$$P(a|k) = \begin{cases} \pi_1(k), a = 1 \\ \pi_a(k) \prod_{i=1}^{a-1} \left(1 - \pi_i(k)\right), a = 2,3,\ldots,A-1 \\ \prod_{i=1}^{A-1} \left(1 - \pi_i(k)\right), a = A \end{cases}$$

The R (R project, 2009) code for implementing smooth ALKs was obtained from Appendix A in Stari et al. (2010).

ALK Construction and Testing
The following smooth ALKs were constructed:

- overall ALK (all years and regions combined)
- regional ALKs (all years combined)
- yearly ALKs (all regions combined)
- year-region ALKs

Regional delineations followed the definitions outlined during the Red Snapper Stock ID workshop:

- Eastern (E): NMFS grid 1-6
- Central (C): NMFS grid 7-12
- Western (W): NMFS grid 13-21

Since the Smooth ALK uses Maximum Likelihood Estimation and stratum-specific ALKs are nested within a larger model (e.g. regional ALKs nested within the overall ALK), a likelihood ratio test can be used (see Gerritsen et al. 2006, Stari et al. 2010) to test whether keys from the nested model (e.g., regional ALKs, yearly ALKs) are significantly different from the ALK obtained from the combined dataset (e.g. overall ALK). This is achieved by calculating the log likelihood (over common length classes and M common age classes) for each nested key separately (say l_1 and l_2) and the key built from the combined datasets (say l_c) and calculating the test statistic $\Lambda = 2(l_1 + l_2 - l_c)$. Under the null hypothesis that there is no significant difference between the two models, Λ follows a χ^2 distribution with $2(M-1)$ degrees of freedom.

Addressing Age Gaps
While the smooth ALK (Stari et al. 2010) can accommodate many types of data sparsity, one data gap it cannot handle is a gap in ages: if no fish of a certain age have been aged in a certain stratum (i.e. year and region) then that age will not be represented in the smooth ALK. As such, the approach by Stari et al. (2010) was slightly modified to fill in these gaps where they occur.

The process went as follows: if a certain age was missing from the stratum (i.e. year, region, region-year), we sampled the neighboring strata (i.e. the entire dataset for the year or region ALKs, and neighboring regions within the same year for the year-region ALKs) for that age group and extracted the median length corresponding to that age group to create a single data point to fill in the gap. If the missing age was also missing from neighboring strata (i.e. neighboring regions within the same year for the year-region ALKs), we sampled the entire dataset (i.e. all years and regions combined) instead to extract the median length of the missing age group. Table 1, Table 2, Table 3, Table 4, Table 5 and Table 6 provide an overview of sample sizes available to build each ALK and any data filling that has occurred.

Results

The Central region had the highest number of age samples overall, closely followed by the Western region, and the Eastern region had the least (Figure 2 - Figure 4). There were clear differences between regions with older fish being observed farther West (Figure 20, Figure 21 and Figure 22) and many more gaps in ages being observed in the C and E compared with the W, particularly in fish greater than 10 years of age (Table 4, Table 5 and Table 6). All three regions suffered from gaps in age 0 fish sampling.

Proportion-at-age bubble plots (Figure 2 - Figure 19) are a useful tool for tracking cohort strength within a given stock area if the age distributions are representative of the population sampled. It is apparent from the bubble plots in all three regions that the sampling has improved through time, with much clearer signals of recruitment strength (i.e. strong/weak diagonal patterns) appearing starting in the early 2000s. A clear example of that is the strong 2014 year class apparent in the C and E regions (Figure 3 - Figure 4) and the weak 2010 year class apparent in all three regions (Figure 2 - Figure 4).

The likelihood ratio tests revealed that all ALKs were significantly different ($\alpha = 0.05$) than the key they were nested in, indicating that the highest level of stratification (region-year) is preferred.

When comparing the ALKs with years pooled to year-specific ALKs, the year-specific ALKs showed clear signals of alternating weak and strong cohorts that were being masked by the pooled ALK (see example in Figure 23 for the Central region).

The extensive sampling in the West allowed for year-region ALKs to be created with minimal need for gap-filling (Table 4). However, considerable gap-filling was needed for the C and E regions when the 20 year plus group was used (Table 5, Table 6). The 10 year plus group minimized gap filling in all regions (Table 1 - Table 3).

The development of individual year-region ALKs is shown in Figures 20-92. In general, the smooth ALK returned reasonable results, but there are a few instances where low sample sizes and gap filling in the largest age groups led to questionable results. One example of that is shown in Figure 46 where the ALK for 2005 for the Central region showed a high proportion of 14 year old fish present in the last 7 length bins, where no fish age 15-19 are present. This is due to the fact that no fish aged 15-19 had been sampled and these had to be back-filled with fish that were smaller in length (~high 70s) than the six 14 year old fish observed (79-84 cm). A more drastic example of that is visible in Figure 49 where no 20+ fish are allocated to in the last 5 length bins due to the dominance of age 15 fish. In that year and region, two 15 year old fish with lengths 81 and 86 cm were sampled and all the older fish sampled (ages 16-20+) were 81 cm in length or smaller.

Most year-region combinations lacked age 0 fish and had to be back-filled with fish from neighboring strata. While gap-filling appeared to work well in some cases, it performed poorly when very small sample sizes of age 1 fish were available. For example, 2006 in the Western region (Figure 19) shows an instance where two age 1 fish were sampled and because these samples had very large lengths (39 and 42cm), no age 1 fish appeared in the final Smooth ALK. A couple of the earliest years (Figure 9 and 65) had nearly no data available and resulted in a smooth ALK that was a near complete extrapolation of neighboring data.

Discussion

The use of year-region ALKs over regional (i.e. pooled years) ALKs will result in more accurate estimates of age composition and recruitment variability. There are clear signs of strong cohorts in the year-region smooth ALK (e.g. the 2014 cohort in the East).

Some gap filling was needed to calculate probabilities for missing age groups, particularly for the Central and Eastern regions. In the end, determining the impact that the gap-filling procedure may have on final age composition estimates (i.e. once the key is applied to an external length composition dataset) will be highly dependent on how much of the length composition data that the key is applied to lies within the range of length that have been subjected to gap-filling. It will therefore be important to compare the range of lengths of the length composition datasets with the range of lengths that were used to build the keys before applying year-region ALKs to the various datasets.

The objective here was to provide an improvement over regional ALKs (used in SEDAR 52). The strong signals of varying cohort strengths are a clear indication that the year-region smooth ALKs would be an improvement over the regional ALKs. There does exist another alternative approach, however, that could be attempted with red snapper, which is to make use of the Stock Synthesis (SS, Methot and Wetzel 2013) platform directly. SS has a built-in process for converting length composition to age composition given length compositions and age-length pairs (the conditional age-at-length option). The approach differs from the one proposed here in that SS uses a combination of forward ALKs (derived from the age-length pairs) and parametric inverse ALKs (based on the growth curve) to convert lengths to ages, taking into account fleet and survey specific selectivities (see Ailloud et al 2019 and Methot 2000 for more detail). This approach is done on a fleet specific basis. It may therefore still be necessary to rely on smooth ALKs to convert lengths to ages for length composition datasets that do not have any ages associated with them (e.g. discards) if an age-based input is needed.

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Tables

Table 1. Sample sizes available for the W (plus group 10). Grey cells indicate instances where no data were available for that specific age group so samples were filled in from a neighboring stratum (1: data from all regions in that year; 2= data from all years and regions) following the methods outlined in section Addressing Age Gaps.

year	0	1	2	3	4	5	6	7	8	9	10
1996	2	1	1	1	1	1	1	1	2	1	1
1997	2	2	18	6	5	4	1	1	1	1	2
1998	2	15	179	1,086	723	388	140	77	54	29	140
1999	2	1	67	505	907	466	218	85	28	9	17
2000	2	1	68	337	241	201	157	124	67	39	146
2001	2	2	82	208	314	216	206	112	67	36	123
2002	2	66	423	1,339	656	448	192	158	77	37	215
2003	2	3	158	728	817	330	199	118	100	44	240
2004	2	13	380	1,052	934	500	206	149	116	79	347
2005	2	75	652	1,311	891	616	339	171	112	65	217
2006	2	2	361	2,075	1,082	391	338	217	103	62	268
2007	2	11	273	1,252	762	224	168	149	74	49	154
2008	1	204	131	856	1,106	394	165	99	79	62	121
2009	1	3	94	879	1,291	924	302	66	46	68	163
2010	2	205	58	516	1,032	938	497	98	21	14	32
2011	2	4	245	432	1,100	1,414	943	500	127	58	196
2012	7	346	293	1,410	711	1,182	1,102	549	279	73	170

year	0	1	2	3	4	5	6	7	8	9	10
2013	18	280	458	641	2,384	926	832	601	286	132	157
2014	1	55	180	692	738	1,492	461	454	272	131	137
2015	1	3	70	518	947	861	768	269	299	186	208
2016	1	8	100	416	1,245	891	519	343	152	138	347
2017	1	36	215	651	763	1,579	1,038	569	361	189	588
2018	1	2	44	427	872	604	1,047	470	277	211	765
2019	1	2	45	332	799	811	472	481	314	185	873
2020	2	1	27	190	348	417	339	175	202	72	180
2021	1	1	37	302	374	376	313	258	123	95	412
2022	1	1	15	200	413	452	384	288	173	105	600
2023	30	23	36	208	600	617	413	289	194	111	739

Table 2. Sample sizes available for the C (plus group 10). Grey cells indicate instances where no data were available for that specific age group so samples were filled in from a neighboring stratum (1: data from all regions in that year; 2= data from all years and regions) following the methods outlined in section Addressing Age Gaps.

year	0	1	2	3	4	5	6	7	8	9	10
1996	2	2	65	101	22	8	1	3	2	1	2
1997	2	2	111	23	13	3	3	1	1	1	2
1998	2	2	389	1,266	284	59	15	7	5	1	9
1999	2	1	153	981	995	181	88	41	24	21	23
2000	2	14	130	969	594	284	101	27	11	5	4
2001	2	2	323	487	520	265	143	61	20	14	18
2002	2	7	550	2,281	781	407	148	94	18	5	52
2003	2	14	1,230	3,557	2,252	438	217	105	40	14	37
2004	2	14	743	1,962	1,418	624	130	87	41	19	42
2005	2	46	1,403	3,356	1,051	596	248	51	23	11	27
2006	2	29	915	2,348	1,020	285	184	108	25	10	25
2007	2	69	543	1,111	370	71	25	11	8	4	5
2008	3	29	338	745	573	124	28	14	7	7	24
2009	9	41	237	927	675	336	83	22	6	5	4
2010	2	18	191	1,144	1,670	648	359	96	36	14	5
2011	2	4	182	325	1,535	1,589	689	286	77	21	23
2012	6	68	251	924	689	1,748	1,247	435	154	43	32
2013	2	14	336	464	965	485	1,313	935	351	133	56
2014	5	19	167	1,227	810	1,062	467	1,086	682	283	125
2015	7	63	292	1,700	1,714	804	728	431	756	502	263

year	0	1	2	3	4	5	6	7	8	9	10
2016	1	76	1,214	1,041	1,227	651	328	301	194	364	389
2017	1	113	667	2,681	506	519	249	135	120	75	324
2018	1	16	940	1,591	3,512	424	316	127	72	66	294
2019	1	54	262	2,525	1,544	2,392	304	201	58	34	199
2020	2	18	364	608	1,175	535	1,395	134	52	17	126
2021	347	74	289	1,418	822	734	311	801	60	32	96
2022	32	50	274	1,100	1,156	503	405	184	643	37	98
2023	655	178	274	729	767	317	151	138	97	195	90

Table 3. Sample sizes available for the E (plus group 10). Grey cells indicate instances where no data were available for that specific age group so samples were filled in from a neighboring stratum (1: data from all regions in that year; 2= data from all years and regions) following the methods outlined in section Addressing Age Gaps.

year	0	1	2	3	4	5	6	7	8	9	10
1996	2	1	1	1	2	3	1	1	2	1	1
1997	2	2	1	12	18	4	3	1	1	1	2
1998	2	1	4	6	9	11	6	2	1	1	1
1999	2	1	1	18	102	31	24	7	1	2	1
2000	2	1	3	3	23	54	15	6	3	4	5
2001	2	2	1	20	51	37	35	7	1	2	2
2002	2	3	12	37	37	29	35	22	5	3	12
2003	2	1	1	47	71	45	18	17	10	4	10
2004	2	1	10	76	156	79	18	8	4	1	6
2005	2	1	7	104	130	142	46	10	1	1	1
2006	2	1	6	67	173	85	71	21	6	2	9
2007	2	3	3	46	82	54	24	11	3	1	1
2008	1	5	30	96	99	143	39	10	6	2	1
2009	1	11	67	349	368	189	74	19	3	1	1
2010	2	1	29	275	813	708	272	136	34	4	4
2011	2	1	17	157	630	761	362	130	36	14	4
2012	1	8	33	51	227	469	468	176	48	14	14
2013	1	1	24	134	193	443	488	373	163	38	29
2014	6	8	37	319	431	304	429	330	290	154	54
2015	8	38	52	185	558	336	179	241	176	130	69

year	0	1	2	3	4	5	6	7	8	9	10
2016	13	6	422	267	266	411	193	94	105	102	116
2017	1	28	133	1,530	230	183	175	87	49	69	109
2018	1	9	45	209	1,528	183	67	63	32	23	90
2019	19	5	65	214	362	1,266	140	68	32	31	104
2020	2	9	31	142	217	287	715	68	20	12	26
2021	28	5	61	110	378	221	204	439	26	5	29
2022	4	22	54	569	395	691	548	386	987	55	72
2023	9	16	58	226	379	177	240	179	166	197	76

Table 4. Sample sizes available for the W (plus group 20). Grey cells indicate instances where no data were available for that specific age group so samples were filled in from a neighboring stratum (1: data from all regions in that year; 2= data from all years and regions) following the methods outlined in section Addressing Age Gaps.

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1996	2	1	1	1	1	1	1	1	2	1	1	2	1	2	2	2	2	2	2	2	2
1997	2	2	18	6	5	4	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
1998	2	15	179	1,08	723	388	140	77	54	29	29	19	16	15	9	10	9	5	4	1	23
1999	2	1	67	505	907	466	218	85	28	9	7	2	1	1	2	2	2	2	2	1	7
2000	2	1	68	337	241	201	157	124	67	39	26	17	18	10	8	12	6	4	2	2	41
2001	2	2	82	208	314	216	206	112	67	36	20	18	15	12	9	5	11	2	2	3	26
2002	2	66	423	1,33	656	448	192	158	77	37	30	32	20	12	23	12	15	11	8	4	48
2003	2	3	158	728	817	330	199	118	100	44	36	27	34	20	22	18	20	8	7	3	45
2004	2	13	380	1,05	934	500	206	149	116	79	63	40	47	37	33	26	21	9	11	7	53
2005	2	75	652	1,31	891	616	339	171	112	65	45	30	30	31	24	17	8	4	11	3	14
2006	2	2	361	2,07	1,08	391	338	217	103	62	70	40	33	25	19	20	10	9	4	6	32
2007	2	11	273	1,25	762	224	168	149	74	49	34	33	11	15	9	16	9	3	5	3	16
2008	1	204	131	856	1,10	394	165	99	79	62	37	22	19	4	5	5	6	3	2	2	16
2009	1	3	94	879	1,29	924	302	66	46	68	41	24	13	11	14	9	8	3	3	4	33
2010	2	205	58	516	1,03	938	497	98	21	14	5	5	4	1	3	1	3	1	1	2	8
2011	2	4	245	432	1,10	1,41	943	500	127	58	27	32	14	15	7	10	5	10	9	7	60
2012	7	346	293	1,41	711	1,18	1,10	549	279	73	40	15	15	14	9	6	9	13	10	6	33
2013	18	280	458	641	2,38	926	832	601	286	132	38	14	11	17	12	14	6	3	3	9	30
2014	1	55	180	692	738	1,49	461	454	272	131	65	24	10	4	7	7	5	4	3	3	5
2015	1	3	70	518	947	861	768	269	299	186	88	42	14	5	6	6	4	5	5	2	31

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2016	1	8	100	416	1,24	891	519	343	152	138	132	81	55	20	9	11	7	8	8	1	16
2017	1	36	215	651	763	1,57	1,03	569	361	189	180	156	99	48	21	20	9	8	5	5	37
2018	1	2	44	427	872	604	1,04	470	277	211	189	182	172	97	48	20	12	3	9	4	29
2019	1	2	45	332	799	811	472	481	314	185	153	148	149	115	106	65	42	21	13	8	53
2020	2	1	27	190	348	417	339	175	202	72	37	27	29	42	22	8	8	2	1	1	3
2021	1	1	37	302	374	376	313	258	123	95	85	64	47	39	40	42	33	17	18	3	24
2022	1	1	15	200	413	452	384	288	173	105	106	75	63	75	61	61	56	31	17	15	40
2023	30	23	36	208	600	617	413	289	194	111	88	85	81	80	57	88	82	57	39	30	52

Table 5. Sample sizes available for the C (plus group 20). Grey cells indicate instances where no data were available for that specific age group so samples were filled in from a neighboring stratum (1: data from all regions in that year; 2= data from all years and regions) following the methods outlined in section Addressing Age Gaps.

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1996	2	2	65	101	22	8	1	3	2	1	2	2	1	2	2	2	2	2	2	2	2
1997	2	2	111	23	13	3	3	1	1	1	2	2	2	2	2	2	2	2	2	2	2
1998	2	2	389	1,26	284	59	15	7	5	1	1	1	1	1	1	1	1	1	1	1	6
1999	2	1	153	981	995	181	88	41	24	21	12	5	1	2	2	2	2	2	2	1	3
2000	2	14	130	969	594	284	101	27	11	5	1	3	1	1	1	1	1	1	1	1	1
2001	2	2	323	487	520	265	143	61	20	14	6	5	1	1	1	1	1	1	1	1	4
2002	2	7	550	2,28	781	407	148	94	18	5	7	5	10	9	1	1	1	1	1	2	16
2003	2	14	1,23	3,55	2,25	438	217	105	40	14	4	4	4	1	2	1	2	2	2	1	15
2004	2	14	743	1,96	1,41	624	130	87	41	19	5	7	9	5	1	5	1	1	1	1	10
2005	2	46	1,40	3,35	1,05	596	248	51	23	11	12	1	1	3	6	1	1	1	1	1	3
2006	2	29	915	2,34	1,02	285	184	108	25	10	6	3	3	2	2	2	2	1	1	1	3
2007	2	69	543	1,11	370	71	25	11	8	4	2	1	1	1	1	1	1	1	1	1	1
2008	3	29	338	745	573	124	28	14	7	7	5	3	3	1	3	2	2	1	1	1	4
2009	9	41	237	927	675	336	83	22	6	5	1	1	1	1	1	1	1	1	1	1	1
2010	2	18	191	1,14	1,67	648	359	96	36	14	3	1	1	1	1	1	1	1	1	2	1
2011	2	4	182	325	1,53	1,58	689	286	77	21	5	4	1	1	4	1	1	1	1	1	6
2012	6	68	251	924	689	1,74	1,24	435	154	43	14	6	1	2	1	2	1	2	2	1	3
2013	2	14	336	464	965	485	1,31	935	351	133	30	11	4	5	2	1	1	1	1	1	1
2014	5	19	167	1,22	810	1,06	467	1,08	682	283	83	21	8	6	4	1	1	1	2	1	1
2015	7	63	292	1,70	1,71	804	728	431	756	502	181	51	19	7	2	1	1	1	1	1	2

year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
2016	1	76	1,21	1,04	1,22	651	328	301	194	364	224	100	42	9	6	1	3	1	1	1	4
2017	1	113	667	2,68	506	519	249	135	120	75	120	107	54	22	8	5	4	1	1	1	2
2018	1	16	940	1,59	3,51	424	316	127	72	66	35	87	85	39	22	13	5	3	1	3	1
2019	1	54	262	2,52	1,54	2,39	304	201	58	34	43	22	48	31	26	10	5	6	1	1	6
2020	2	18	364	608	1,17	535	1,39	134	52	17	20	12	17	19	27	16	7	3	2	1	3
2021	347	74	289	1,41	822	734	311	801	60	32	11	5	11	11	15	16	11	7	5	1	4
2022	32	50	274	1,10	1,15	503	405	184	643	37	13	13	8	5	7	16	18	14	1	1	2
2023	655	178	274	729	767	317	151	138	97	195	17	7	8	7	9	10	9	9	9	1	4

Table 6. Sample sizes available for the E (plus group 20). Grey cells indicate instances where no data were available for that specific age group so samples were filled in from a neighboring stratum (1: data from all regions in that year; 2= data from all years and regions) following the methods outlined in section Addressing Age Gaps.

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1996	2	1	1	1	2	3	1	1	2	1	1	2	1	2	2	2	2	2	2	2	2
1997	2	2	1	12	18	4	3	1	1	1	2	2	2	2	2	2	2	2	2	2	2
1998	2	1	4	6	9	11	6	2	1	1	1	1	1	1	1	1	1	1	1	1	1
1999	2	1	1	18	102	31	24	7	1	2	1	1	1	1	2	2	2	2	2	1	1
2000	2	1	3	3	23	54	15	6	3	4	1	1	1	1	1	1	1	1	1	1	2
2001	2	2	1	20	51	37	35	7	1	2	1	1	1	1	1	1	1	1	1	1	1
2002	2	3	12	37	37	29	35	22	5	3	2	1	1	1	1	1	1	1	1	1	8
2003	2	1	1	47	71	45	18	17	10	4	1	1	1	1	1	1	1	1	1	1	4
2004	2	1	10	76	156	79	18	8	4	1	2	1	1	1	1	1	1	1	1	1	2
2005	2	1	7	104	130	142	46	10	1	1	1	1	1	1	1	1	1	1	1	1	1
2006	2	1	6	67	173	85	71	21	6	2	1	1	1	2	1	1	1	1	1	1	2
2007	2	3	3	46	82	54	24	11	3	1	1	1	1	1	1	1	1	1	1	1	1
2008	1	5	30	96	99	143	39	10	6	2	1	1	1	1	1	1	1	1	1	1	1
2009	1	11	67	349	368	189	74	19	3	1	1	1	1	1	1	1	1	1	1	1	1
2010	2	1	29	275	813	708	272	136	34	4	2	1	1	1	1	1	1	1	1	2	1
2011	2	1	17	157	630	761	362	130	36	14	2	2	1	1	1	1	1	1	1	1	1
2012	1	8	33	51	227	469	468	176	48	14	8	3	1	1	1	1	1	1	1	1	1
2013	1	1	24	134	193	443	488	373	163	38	10	9	3	3	2	1	1	1	1	1	1
2014	6	8	37	319	431	304	429	330	290	154	42	8	1	3	1	1	1	1	1	1	1
2015	8	38	52	185	558	336	179	241	176	130	56	6	2	3	1	1	1	1	1	1	2

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2016	13	6	422	267	266	411	193	94	105	102	69	29	4	5	4	3	1	1	1	1	1
2017	1	28	133	1,53	230	183	175	87	49	69	30	31	36	6	2	2	1	1	1	1	1
2018	1	9	45	209	1,52	183	67	63	32	23	27	23	19	13	3	2	1	1	1	1	2
2019	19	5	65	214	362	1,26	140	68	32	31	22	24	21	16	7	4	3	2	1	1	4
2020	2	9	31	142	217	287	715	68	20	12	8	7	2	3	4	1	1	1	1	1	1
2021	28	5	61	110	378	221	204	439	26	5	8	3	6	4	3	3	1	1	1	1	1
2022	4	22	54	569	395	691	548	386	987	55	11	12	8	13	9	10	3	2	3	1	1
2023	9	16	58	226	379	177	240	179	166	197	23	15	7	6	5	6	5	1	2	2	4

Figures

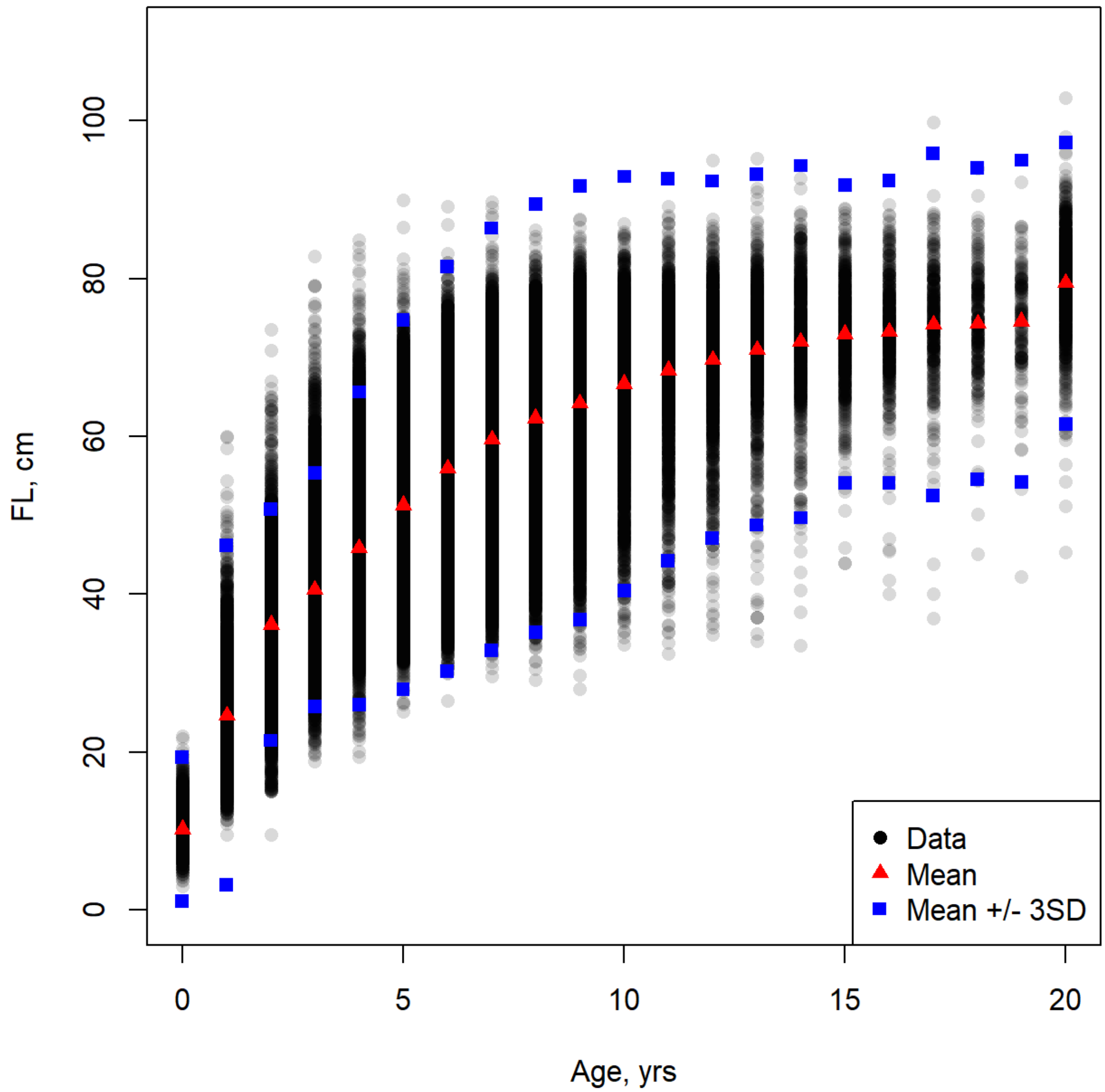

Figure 1: Age-length pairs collected between 1980 and 2023, all sources combined using a plus group of 20. Mean length-at-age and 3 standard deviations about the mean are shown.

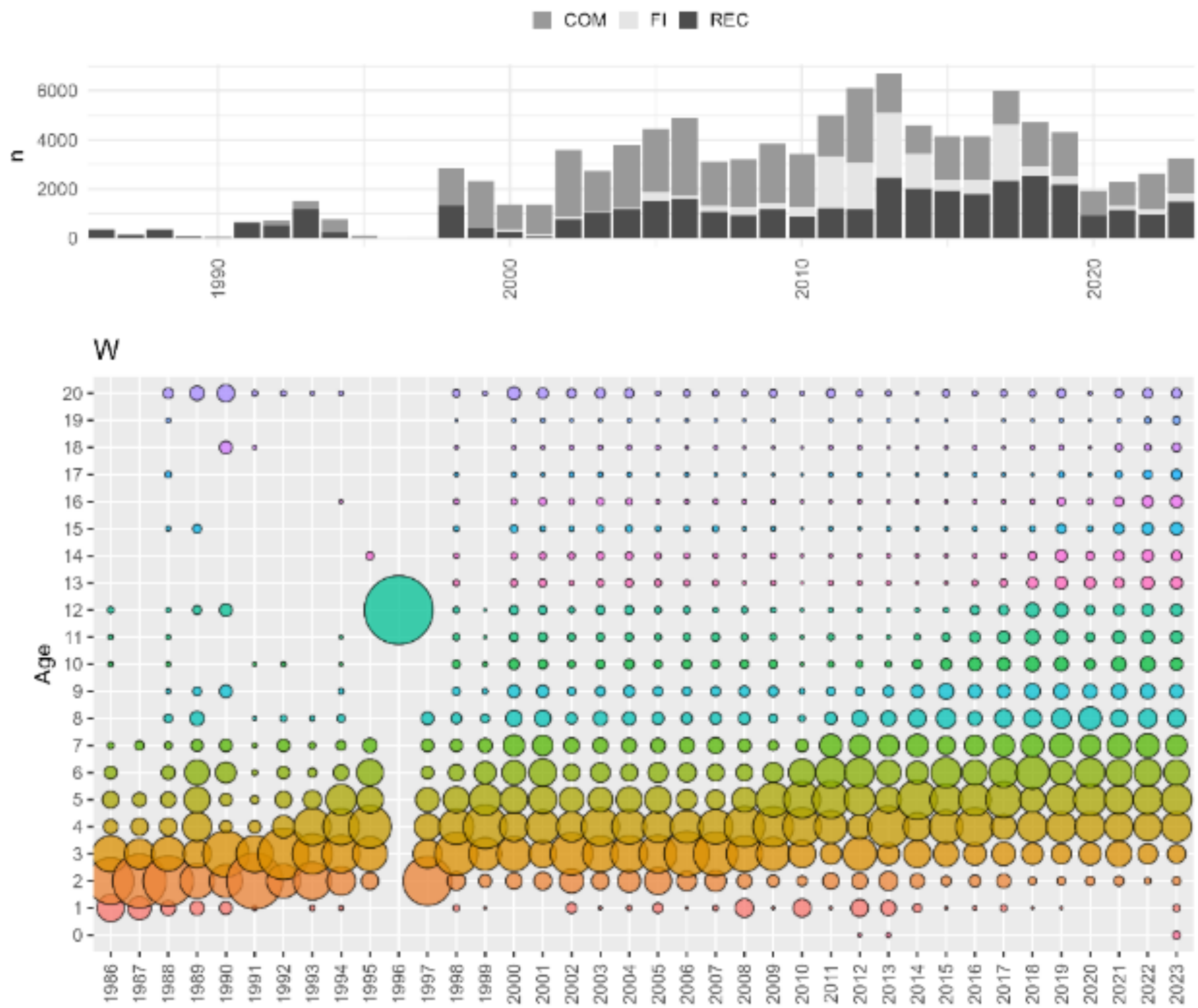

Figure 2: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for all sectors combined in the Western region and associated sample sizes by sector (upper histogram). Cohort progressions are most evident in recent years.

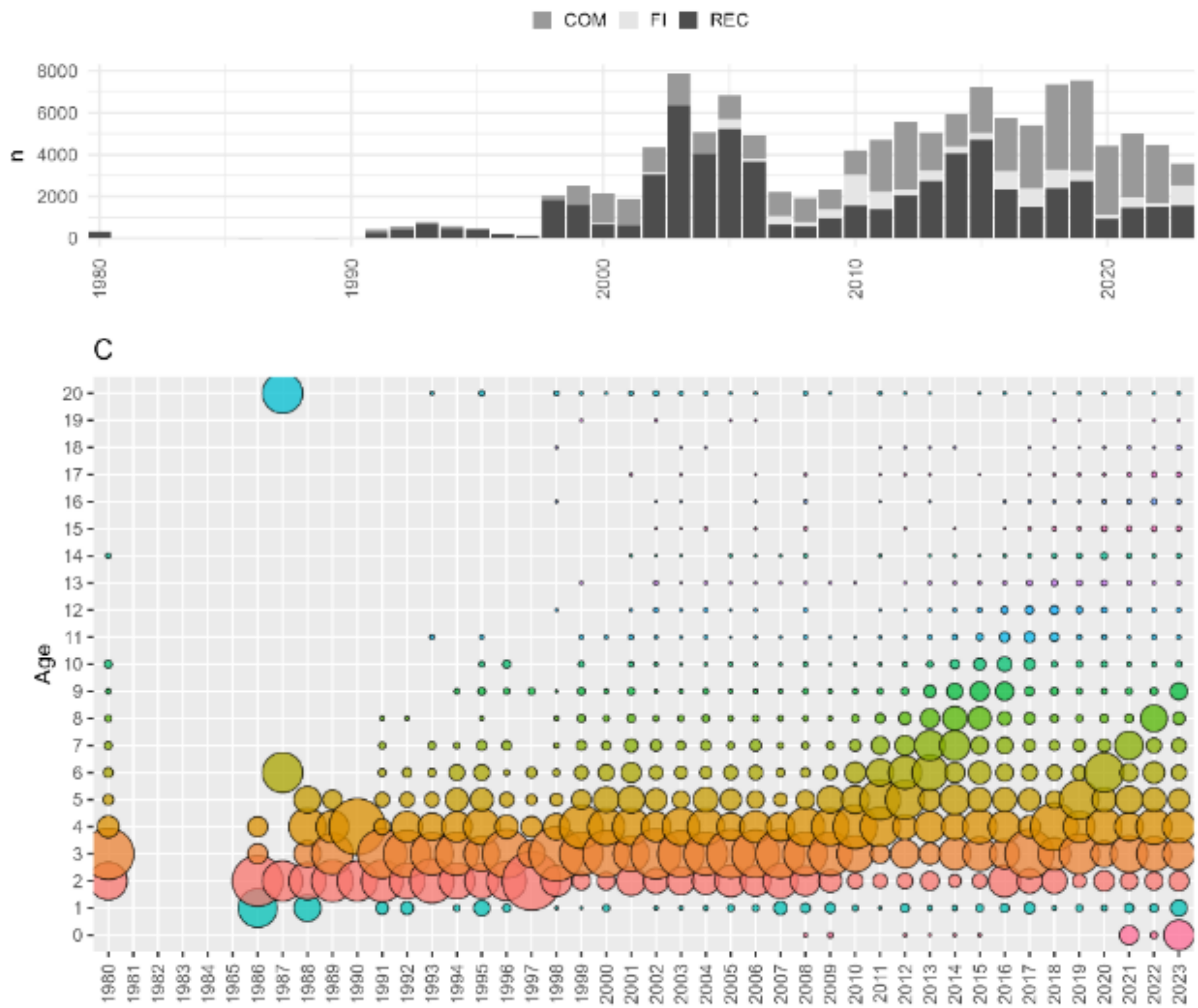

Figure 3: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for all sectors combined in the Central region and associated sample sizes by sector (upper histogram). Cohort progressions are most evident in recent years.

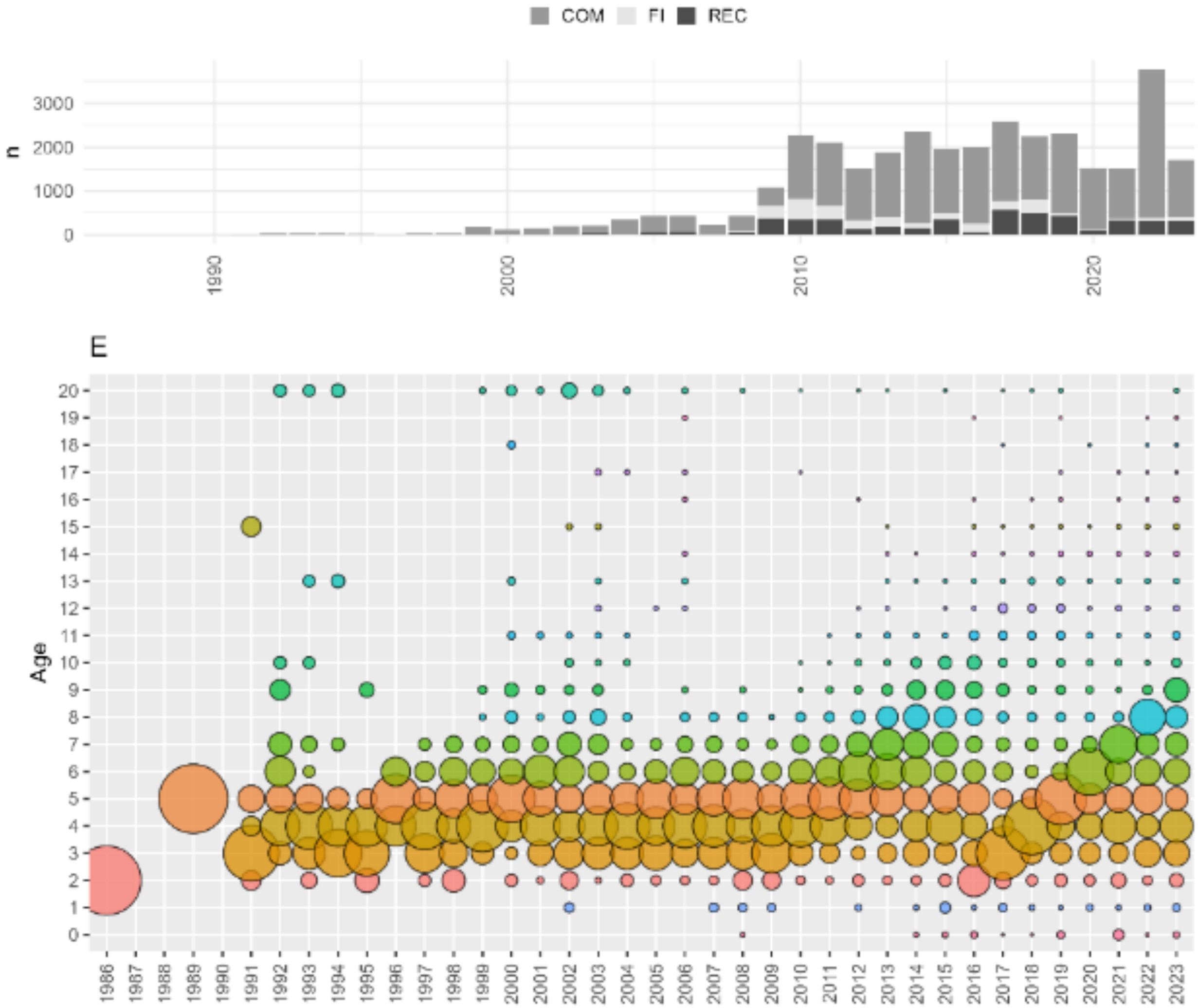

Figure 4: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for all sectors combined in the Eastern region and associated sample sizes by sector (upper histogram). Cohort progressions are most evident in recent years.

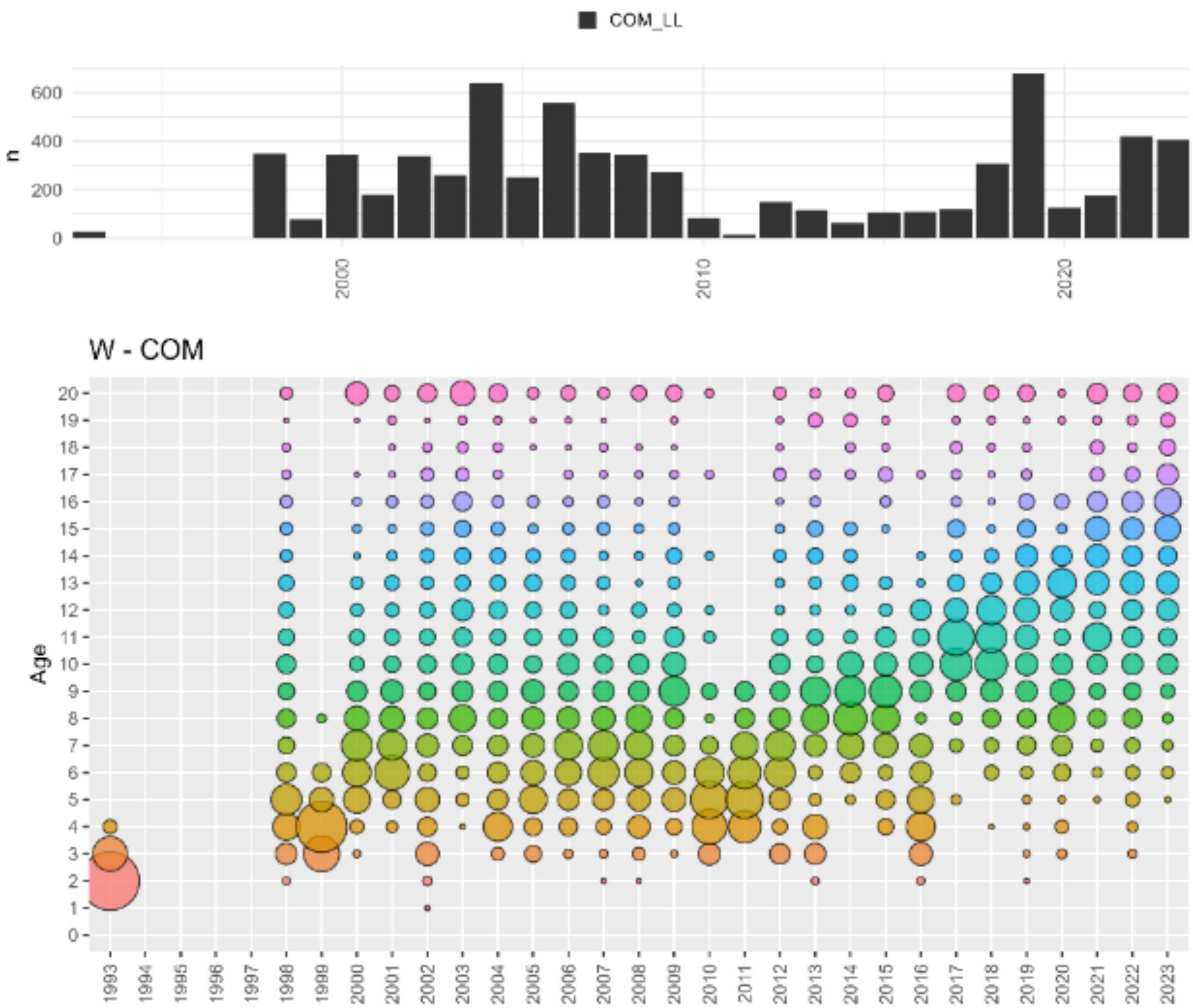

Figure 5: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for commercial LL in the Western region and associated sample sizes (upper histogram).

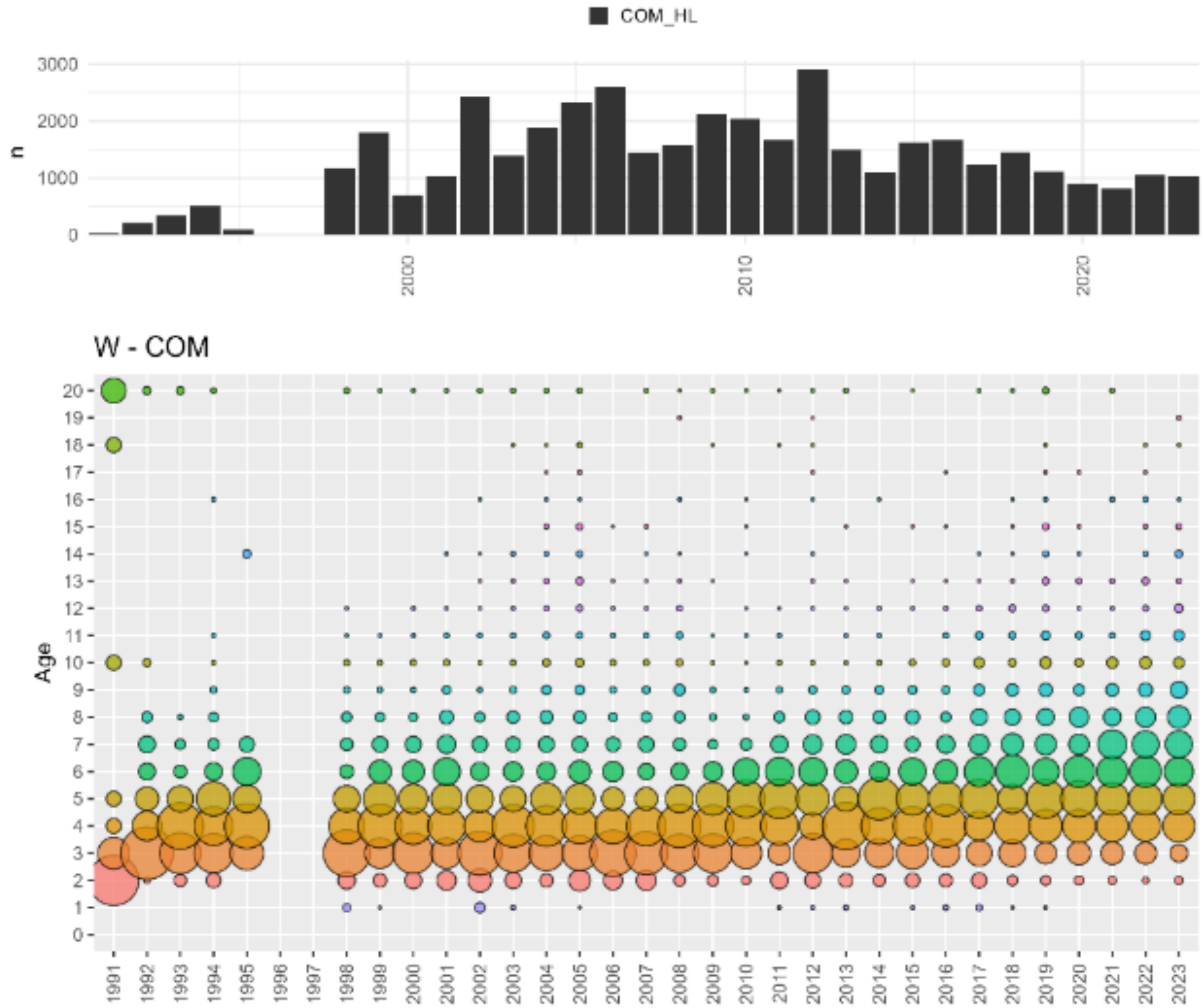

Figure 6: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for commercial HL in the Western region and associated sample sizes (upper histogram).

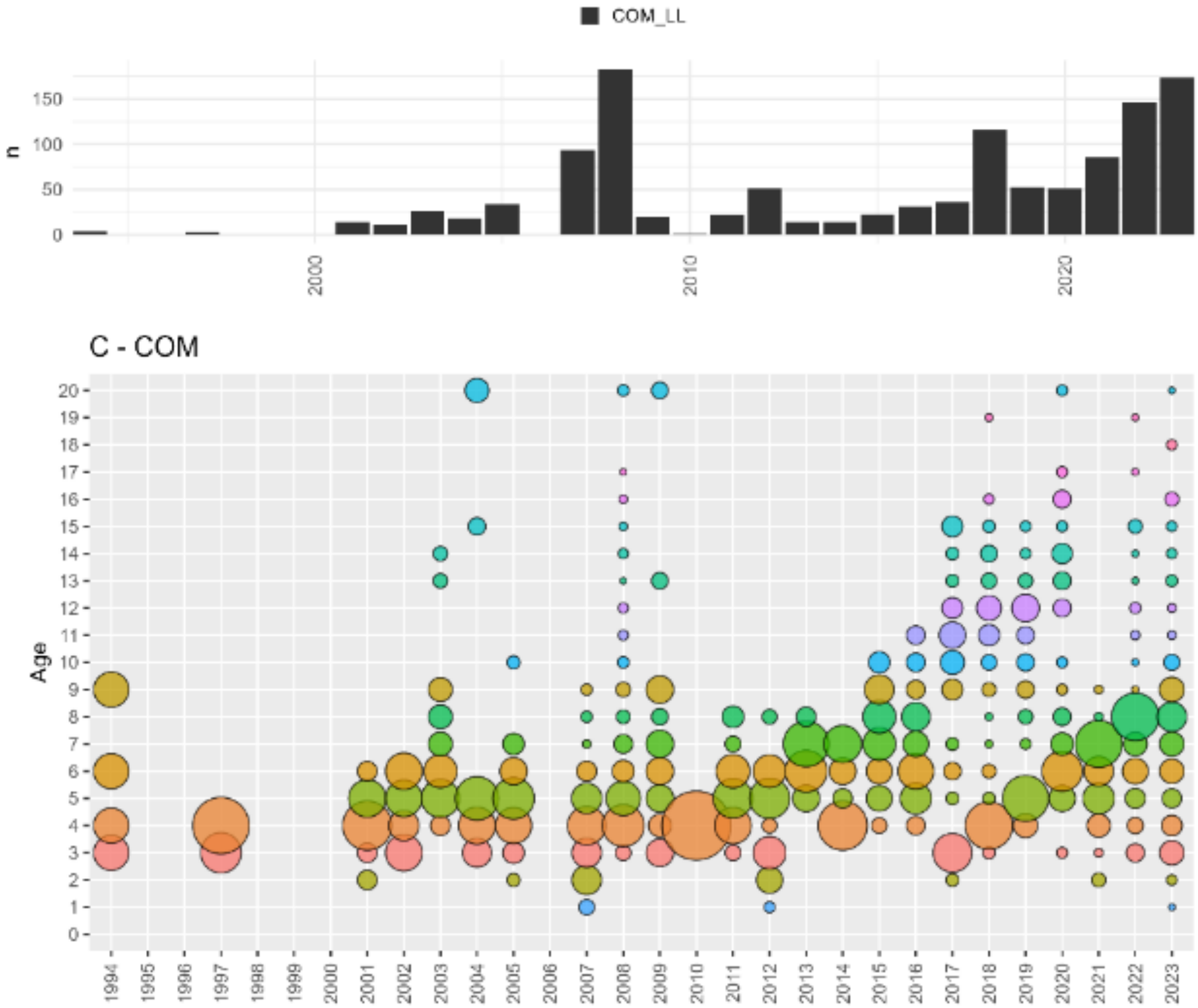

Figure 7: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for commercial LL in the Central region and associated sample sizes (upper histogram).

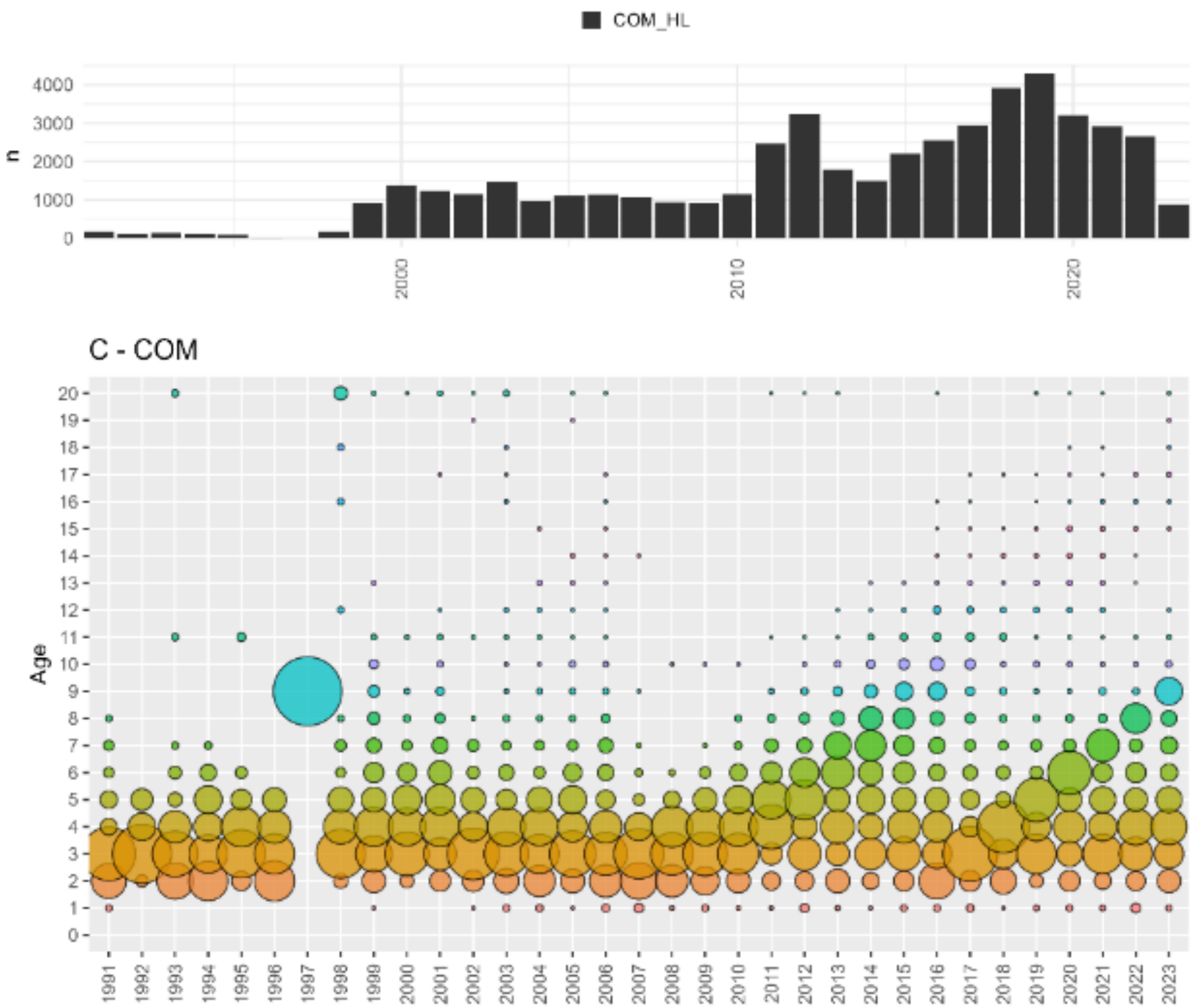

Figure 8: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for commercial HL in the Central region and associated sample sizes (upper histogram).

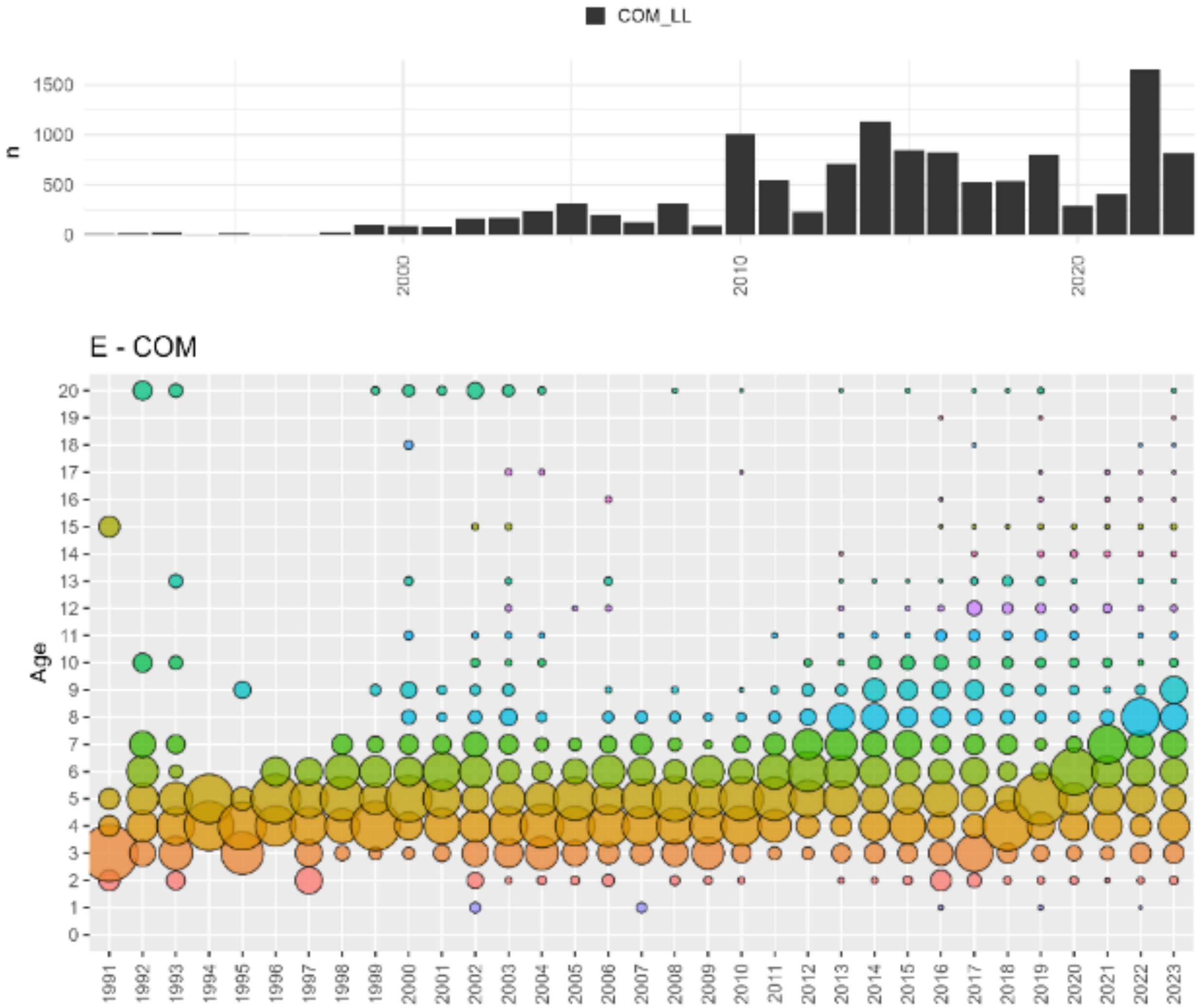

Figure 9: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for commercial LL in the Eastern region and associated sample sizes (upper histogram).

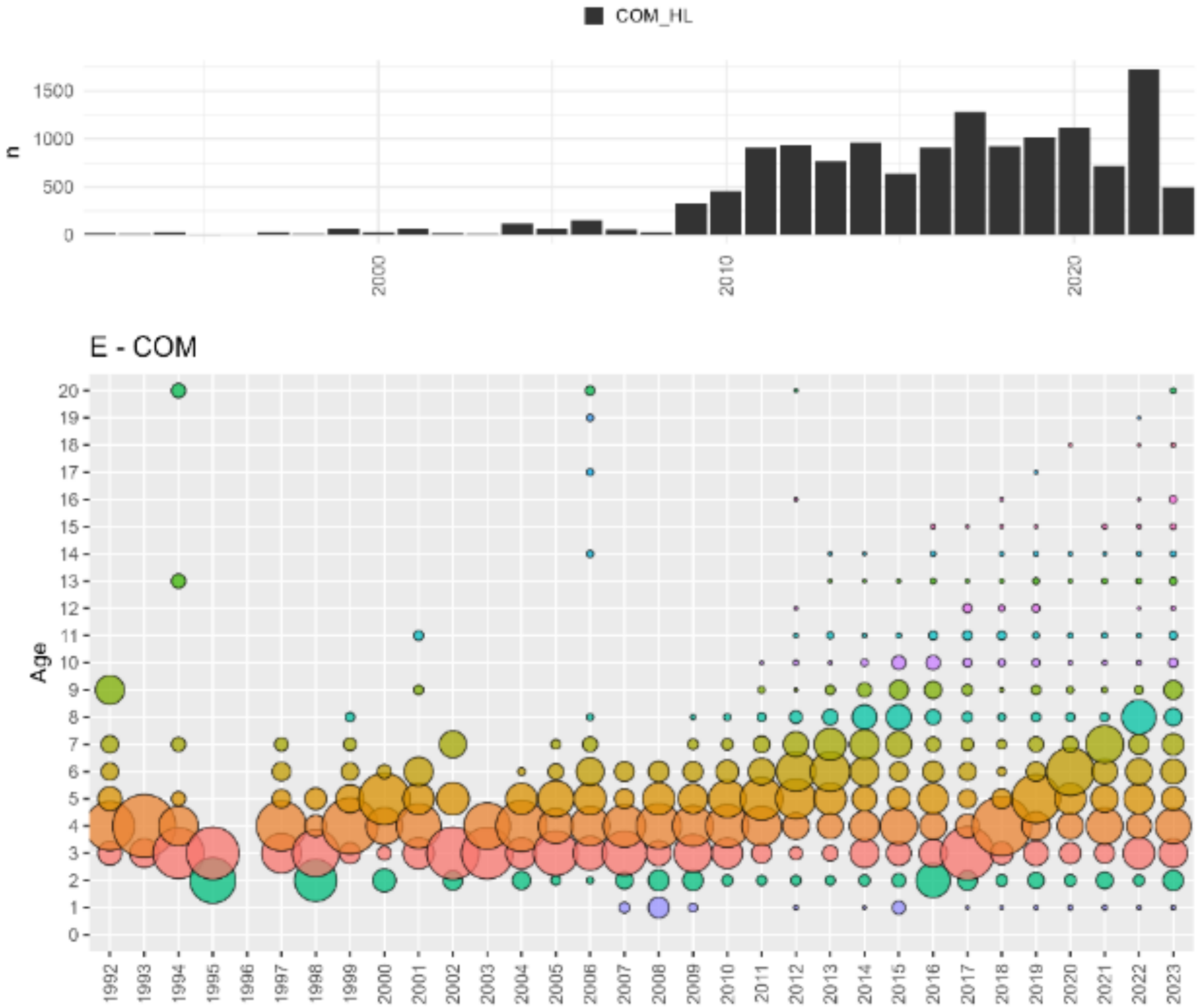

Figure 10: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for commercial HL in the Eastern region and associated sample sizes (upper histogram).

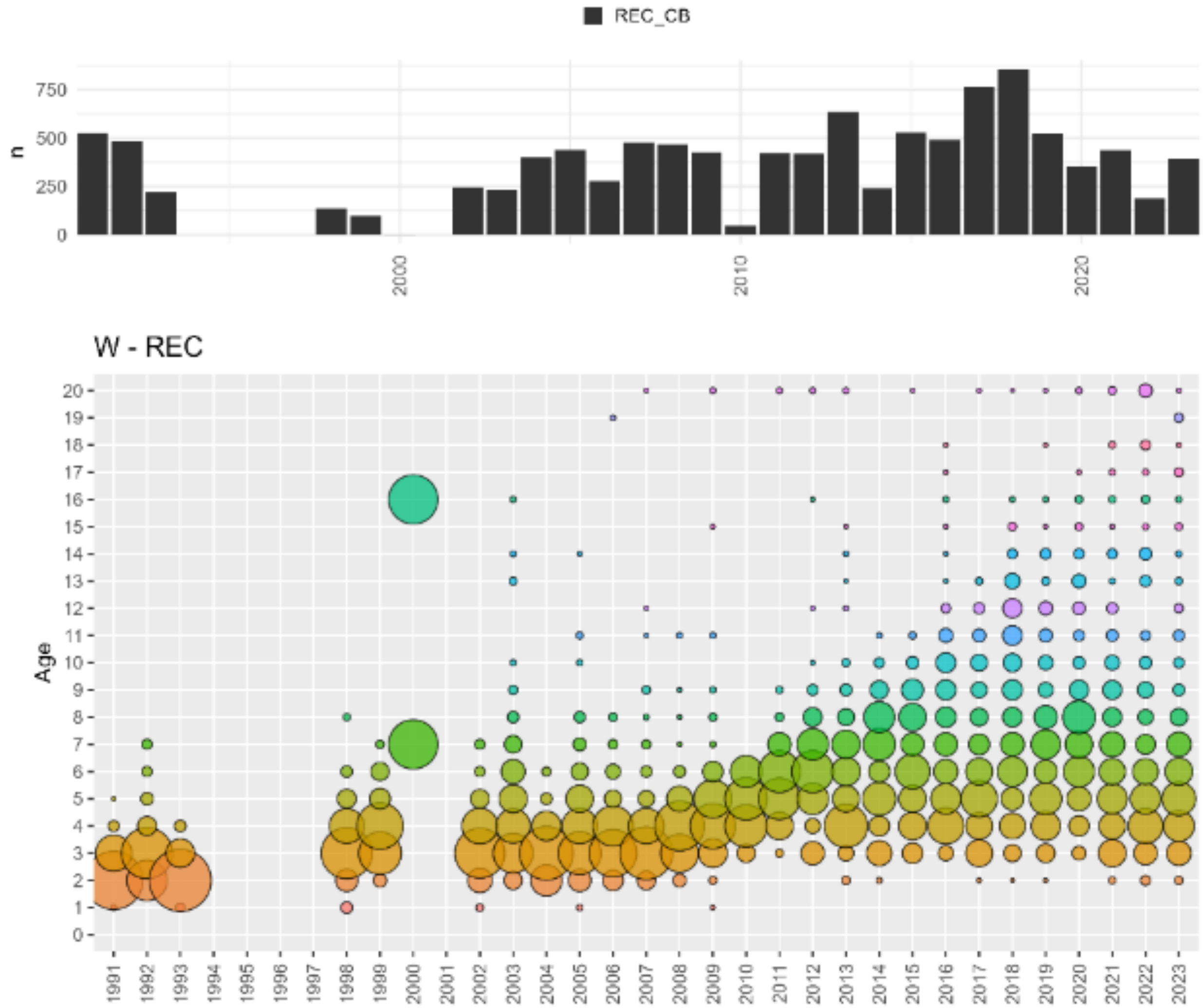

Figure 11: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Charterboat mode in the Western region and associated sample sizes (upper histogram).

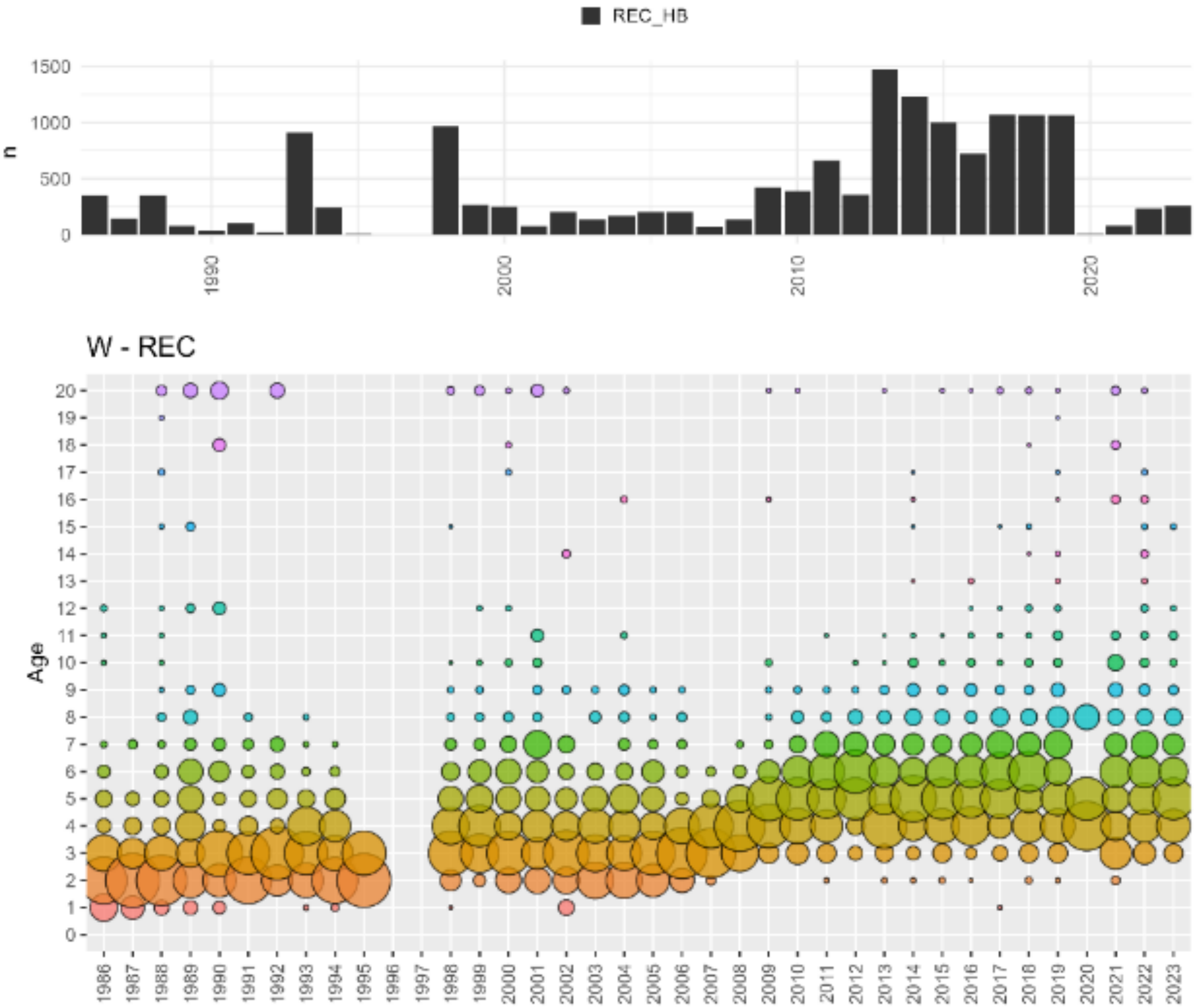

Figure 12: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Headboat mode in the Western region and associated sample sizes (upper histogram).

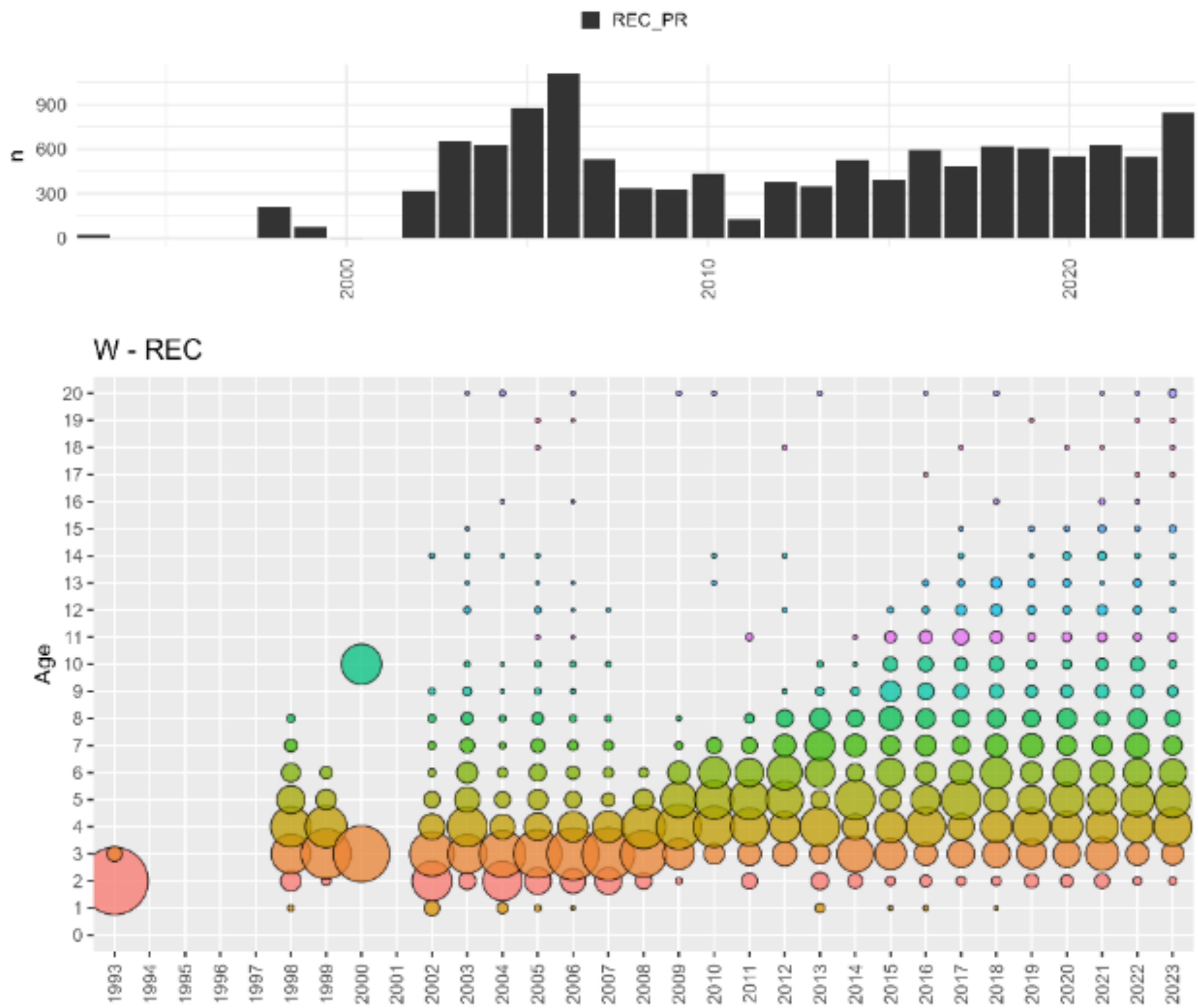

Figure 13: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Private mode in the Western region and associated sample sizes (upper histogram).

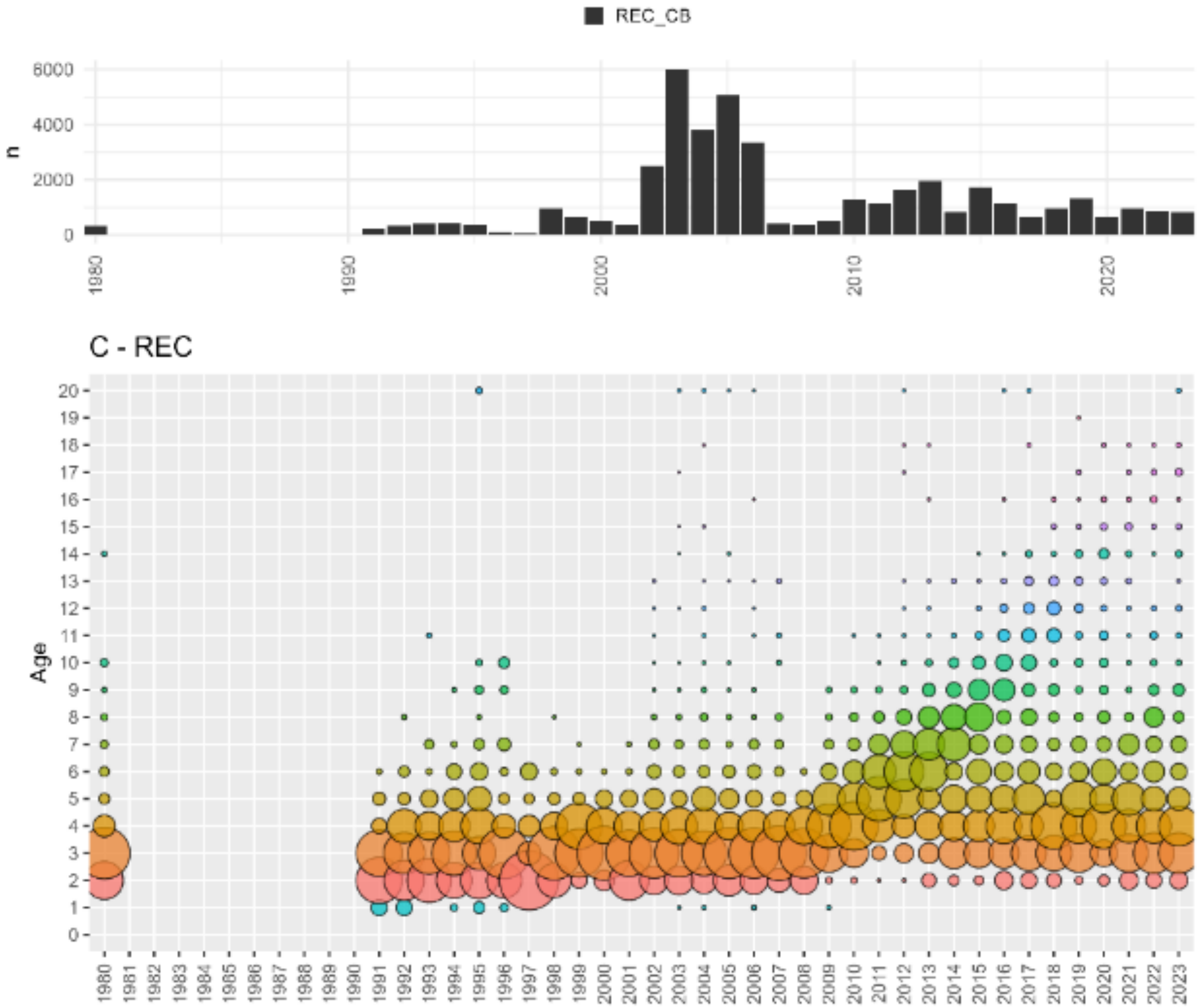

Figure 14: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Charterboat mode in the Central region and associated sample sizes (upper histogram).

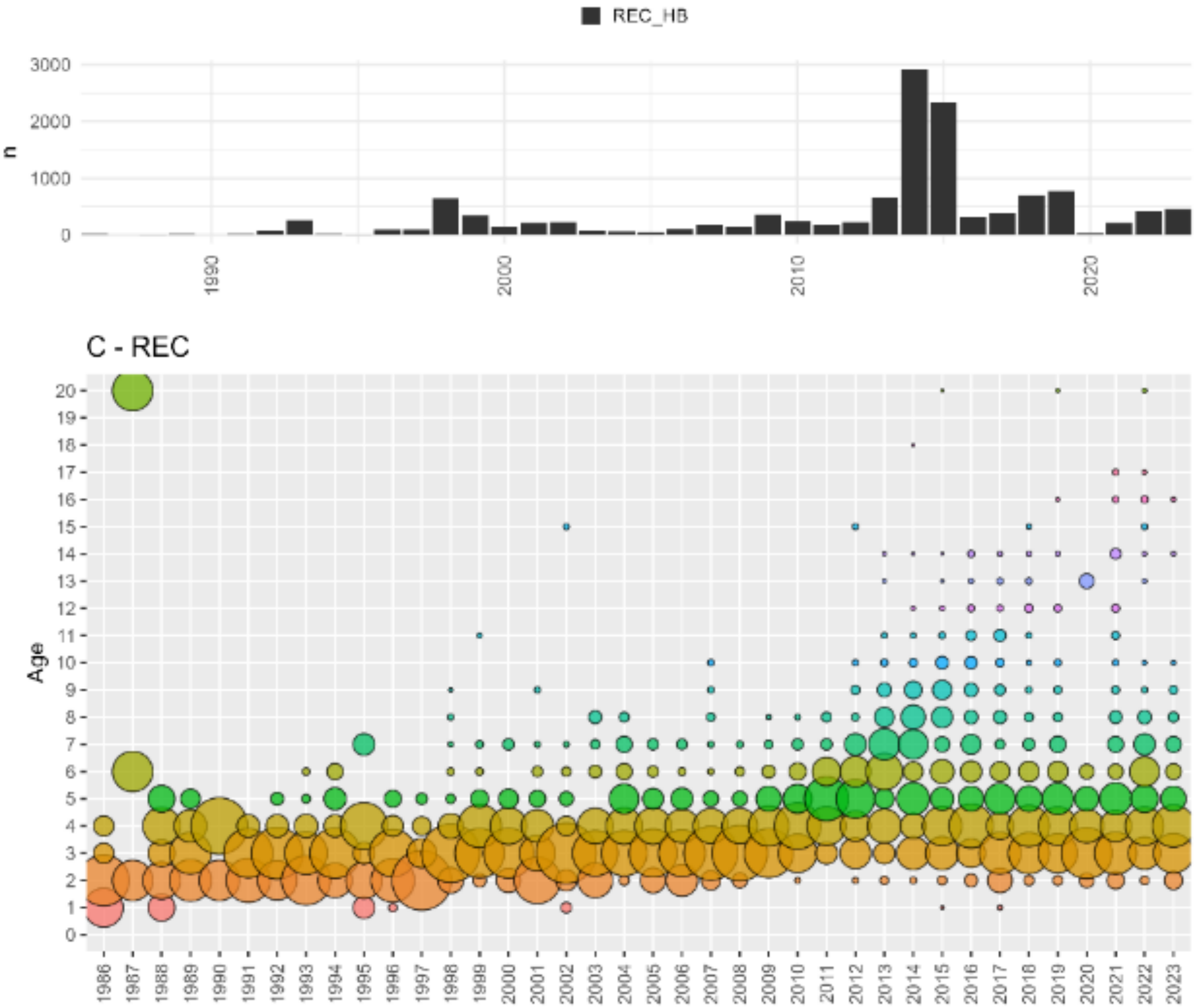

Figure 15: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Headboat mode in the Central region and associated sample sizes (upper histogram).

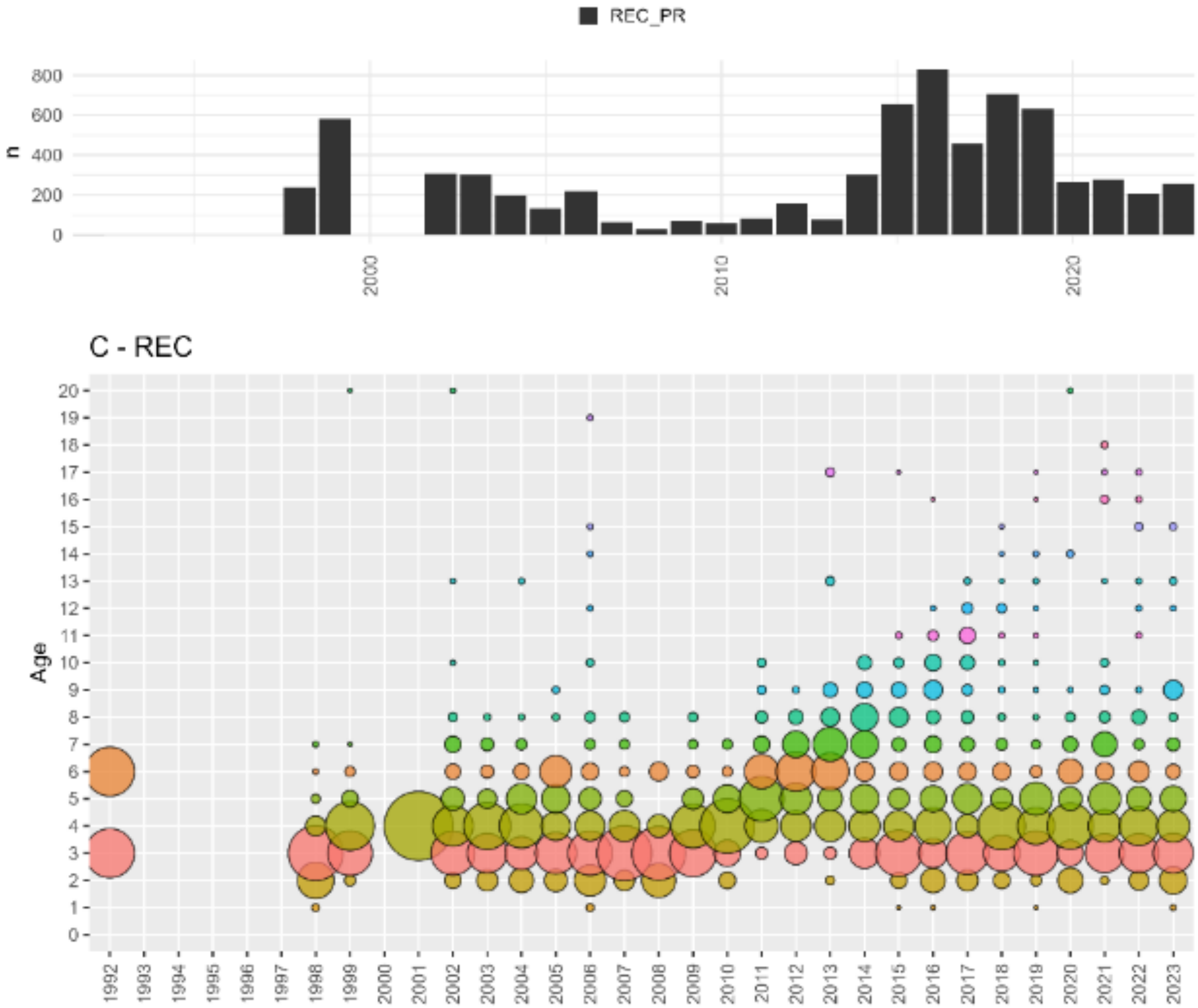

Figure 16: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Private mode in the Central region and associated sample sizes (upper histogram).

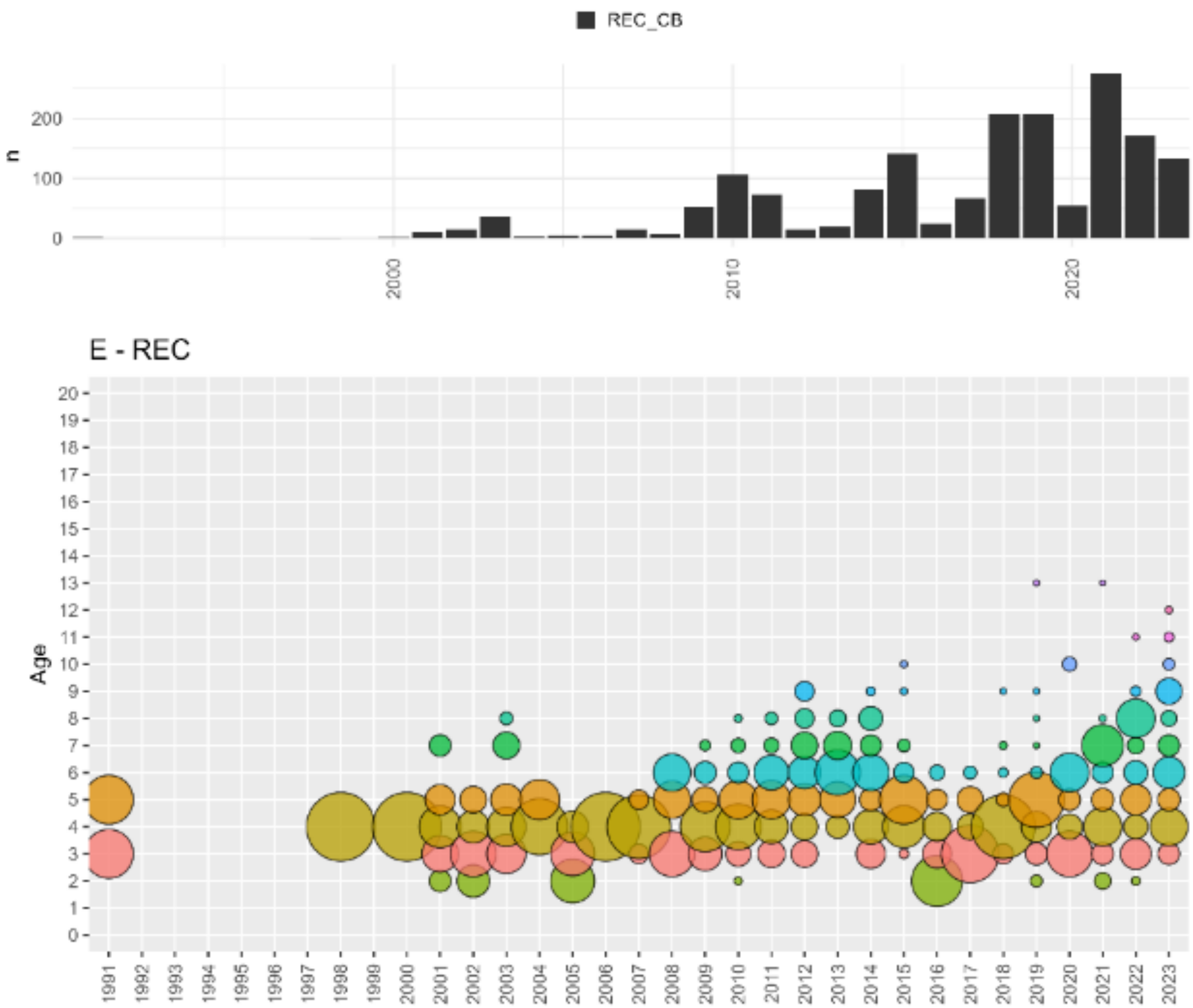

Figure 17: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Charterboat mode in the Eastern region and associated sample sizes (upper histogram).

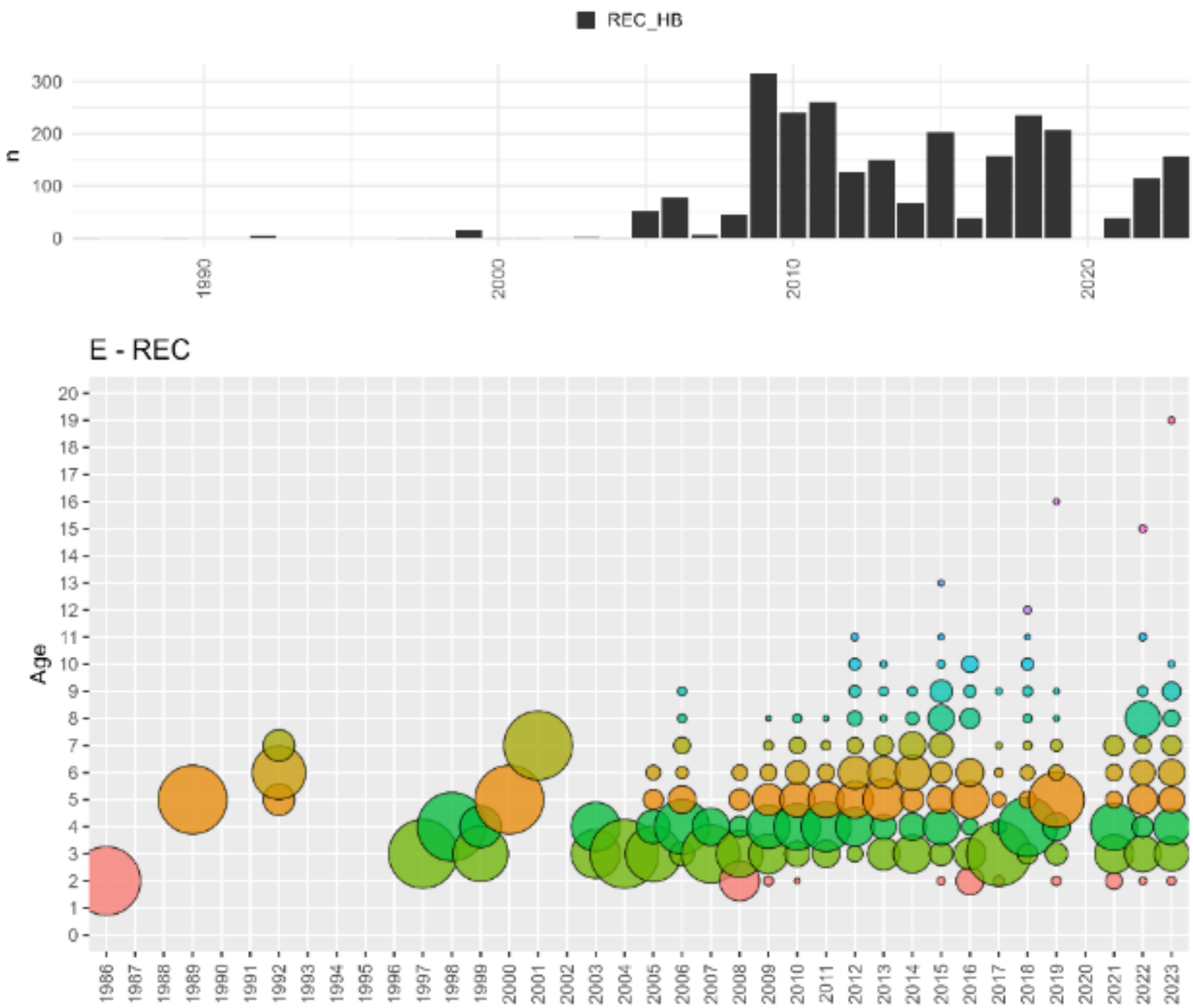

Figure 18: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Headboat mode in the Eastern region and associated sample sizes (upper histogram).

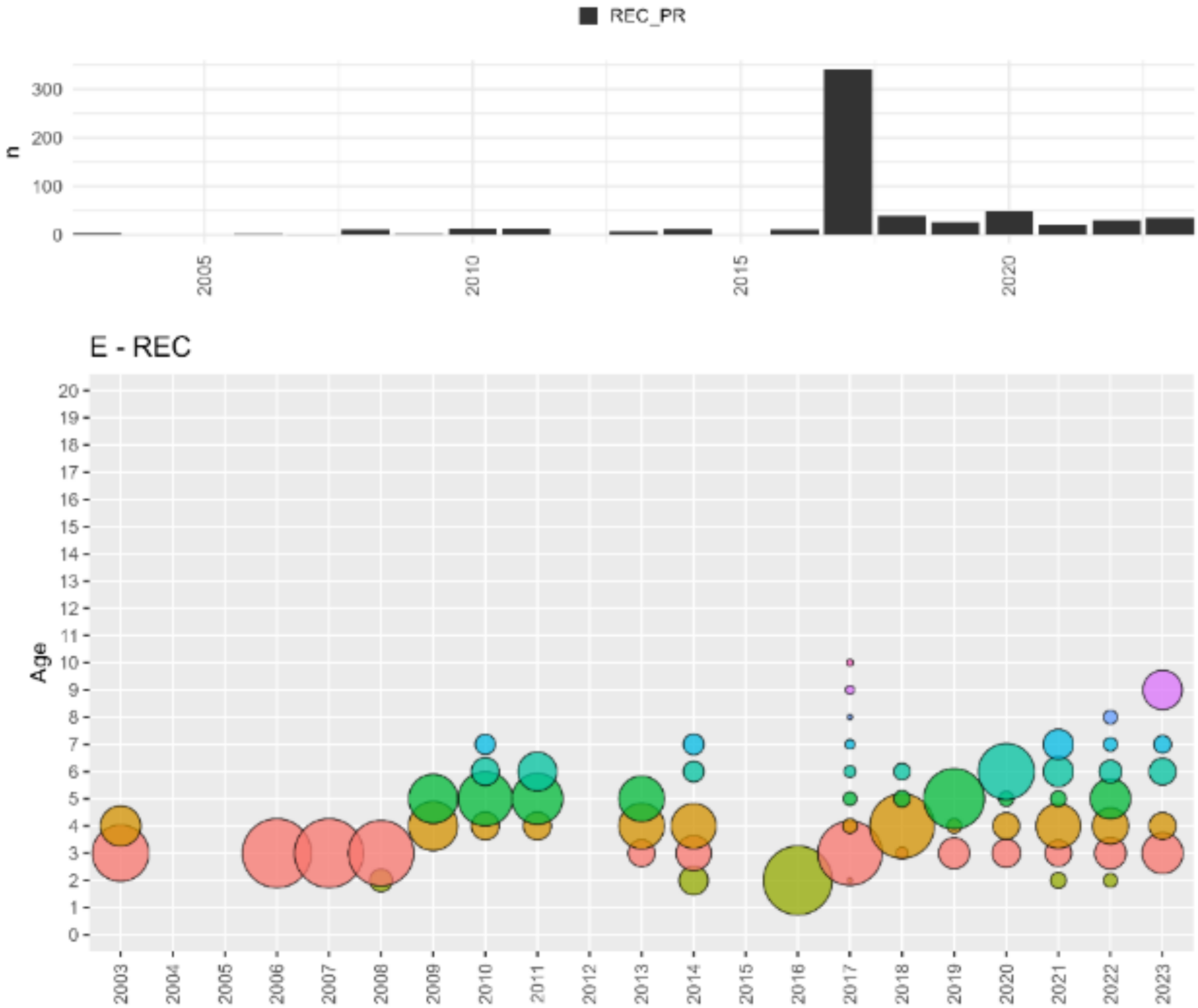

Figure 19: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico red snapper for recreational Private mode in the Eastern region and associated sample sizes (upper histogram).

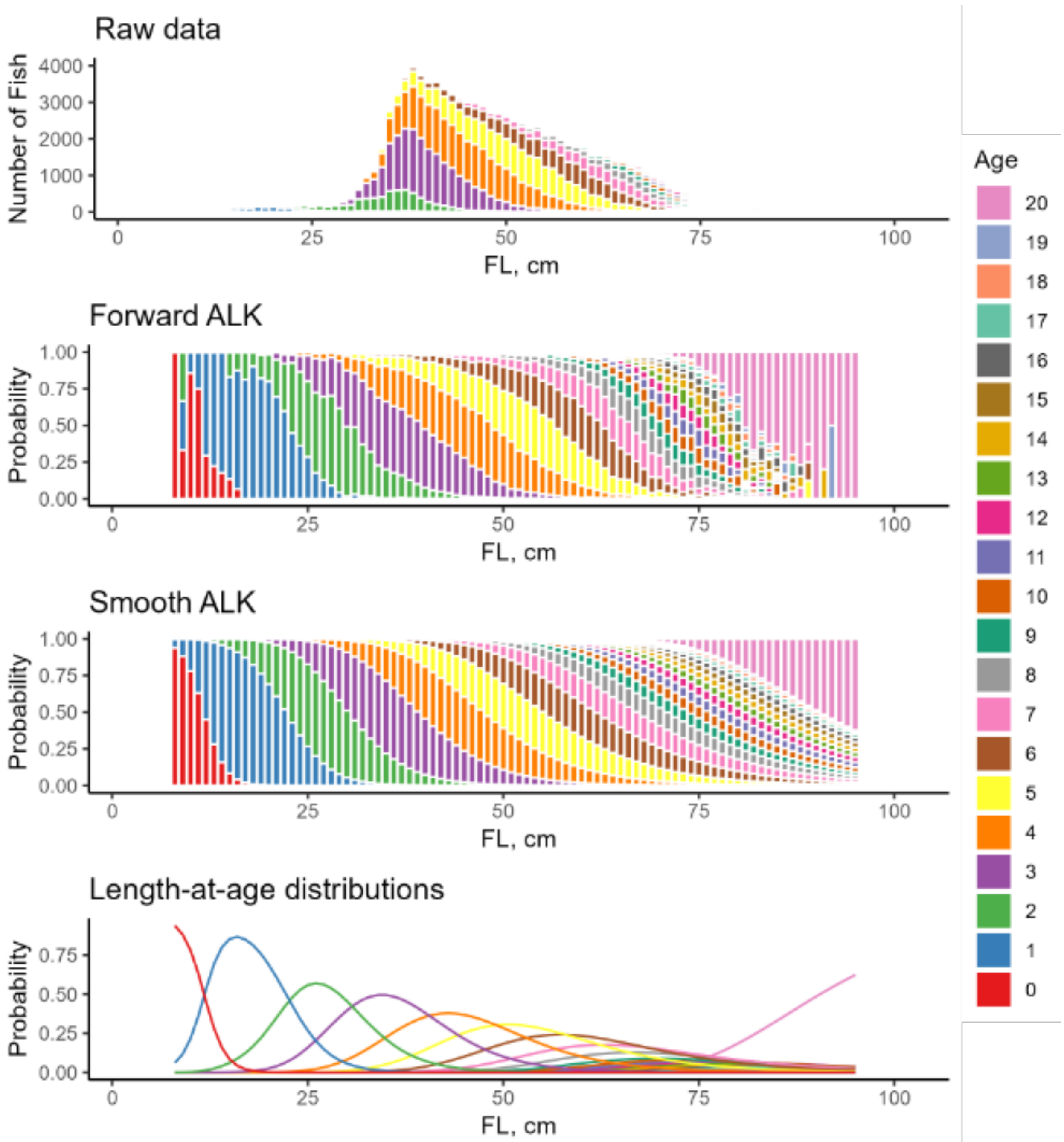

Figure 20: Age data and derived ALKs (pooled years) for the Western region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

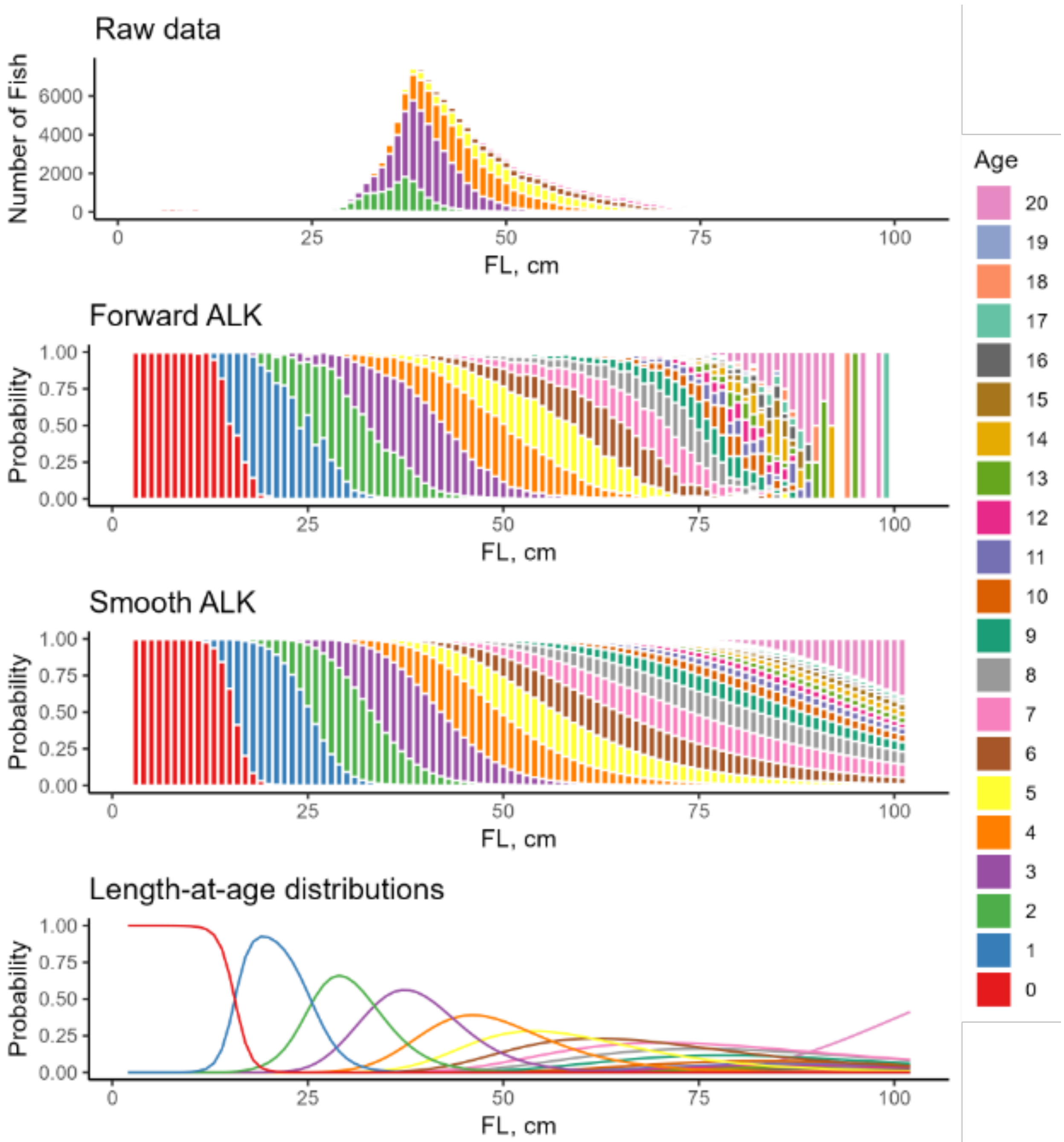

Figure 21: Age data and derived ALKs (pooled years) for the Central region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

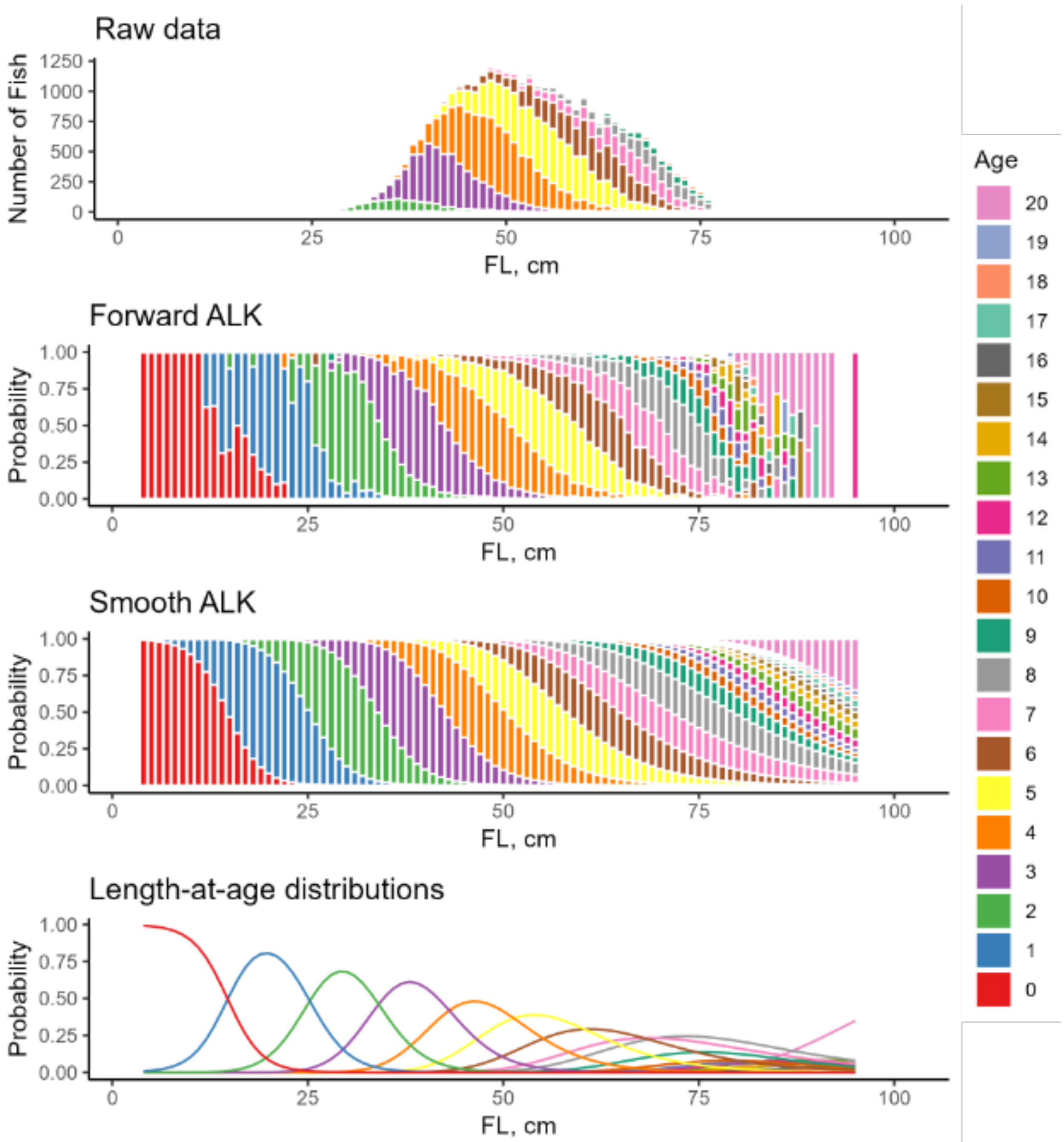

Figure 22: Age data and derived ALKs (pooled years) for the Eastern region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

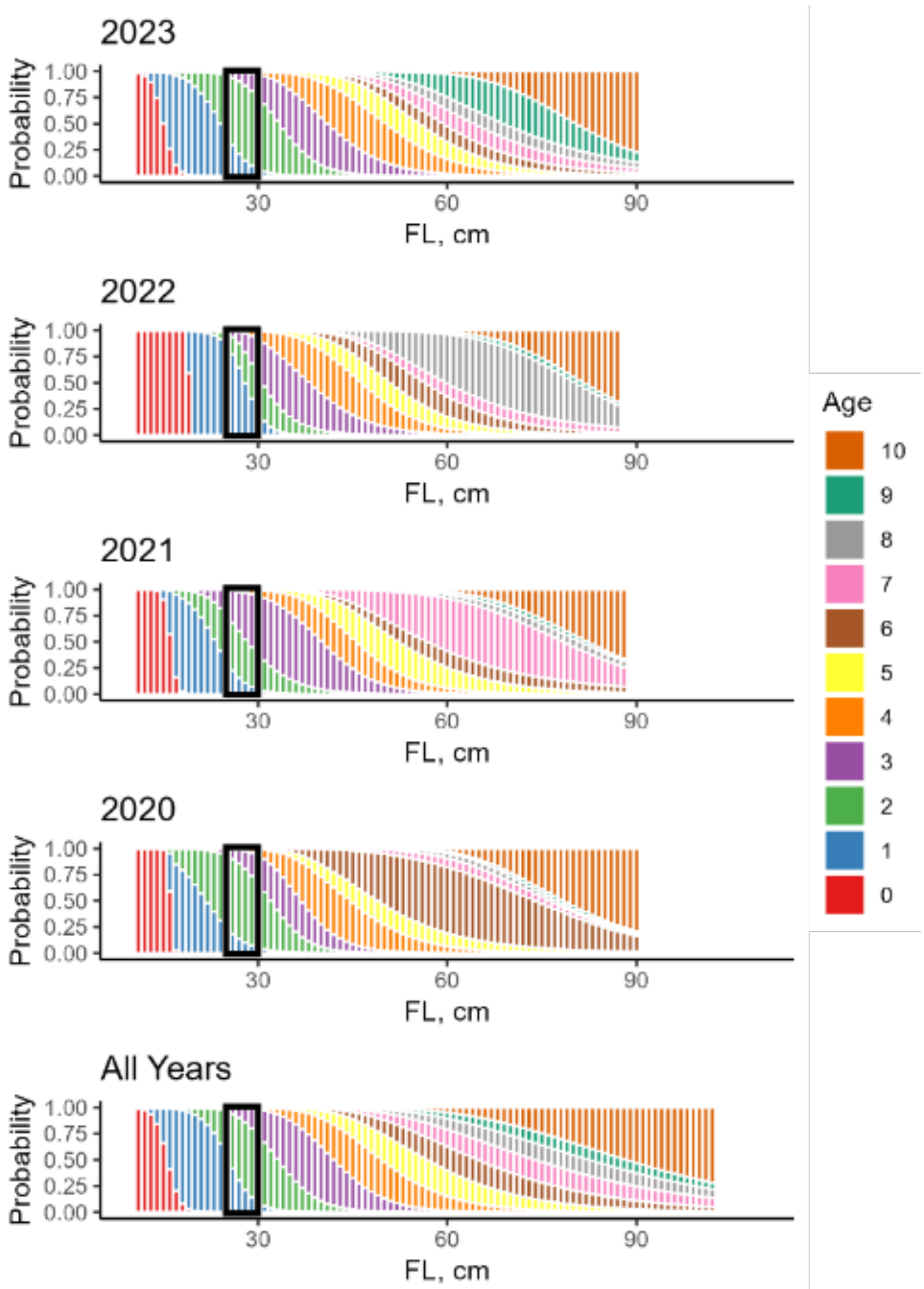

Figure 23: Year-specific ALKs (2020-2023) vs. pooled ALK (All Years) for the Central region. There are clear signals of strong 2018 and 2021 cohorts moving through the population in the year-specific ALKs. The black rectangles show how different the age composition within the 25-30cm length bin is from year to year due to variability in cohort strengths. Applying the pooled ALK to length composition from individual years would mask the true recruitment variability observed in each year.

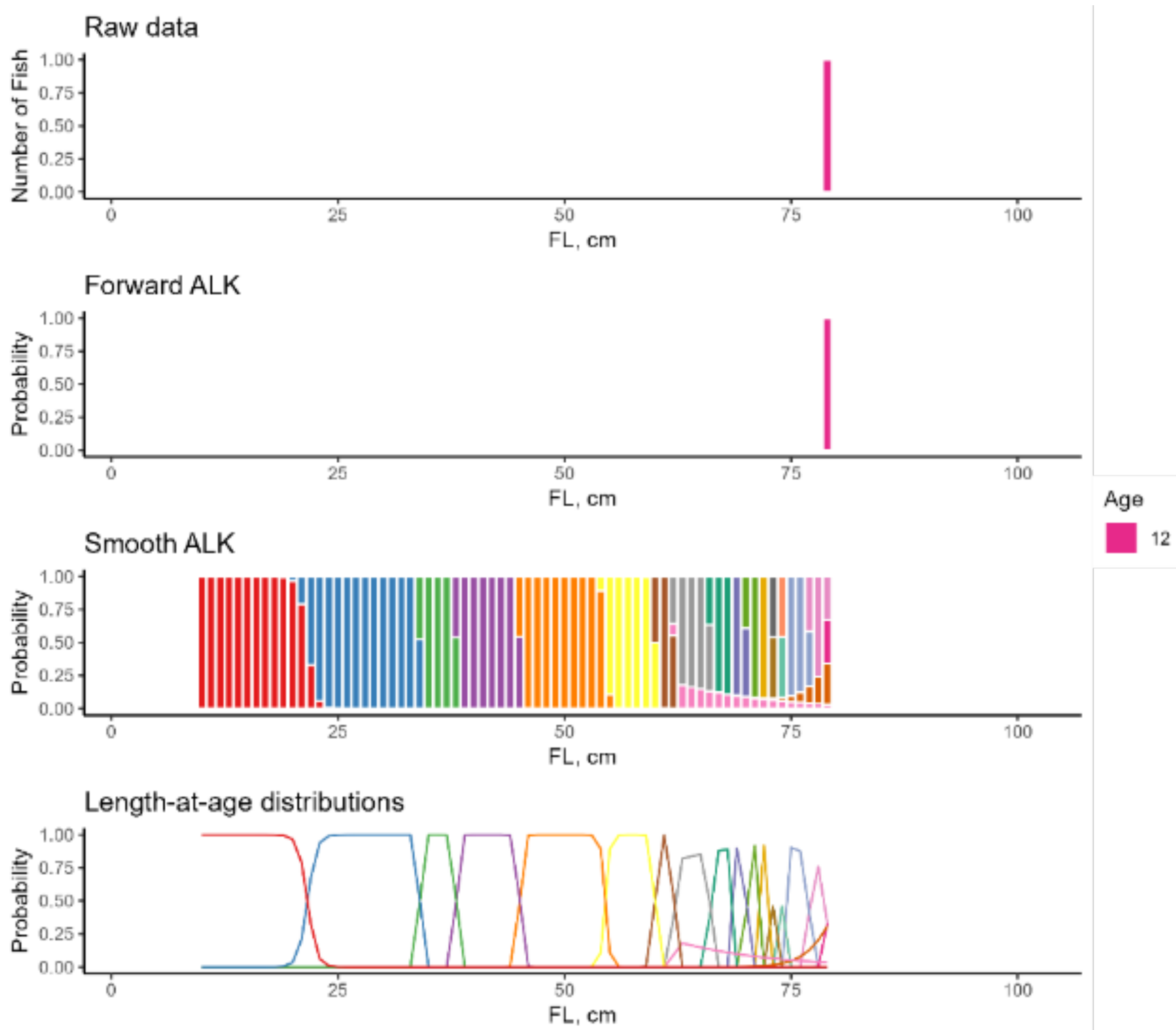

Figure 9. Age data and derived ALKs for 1996 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

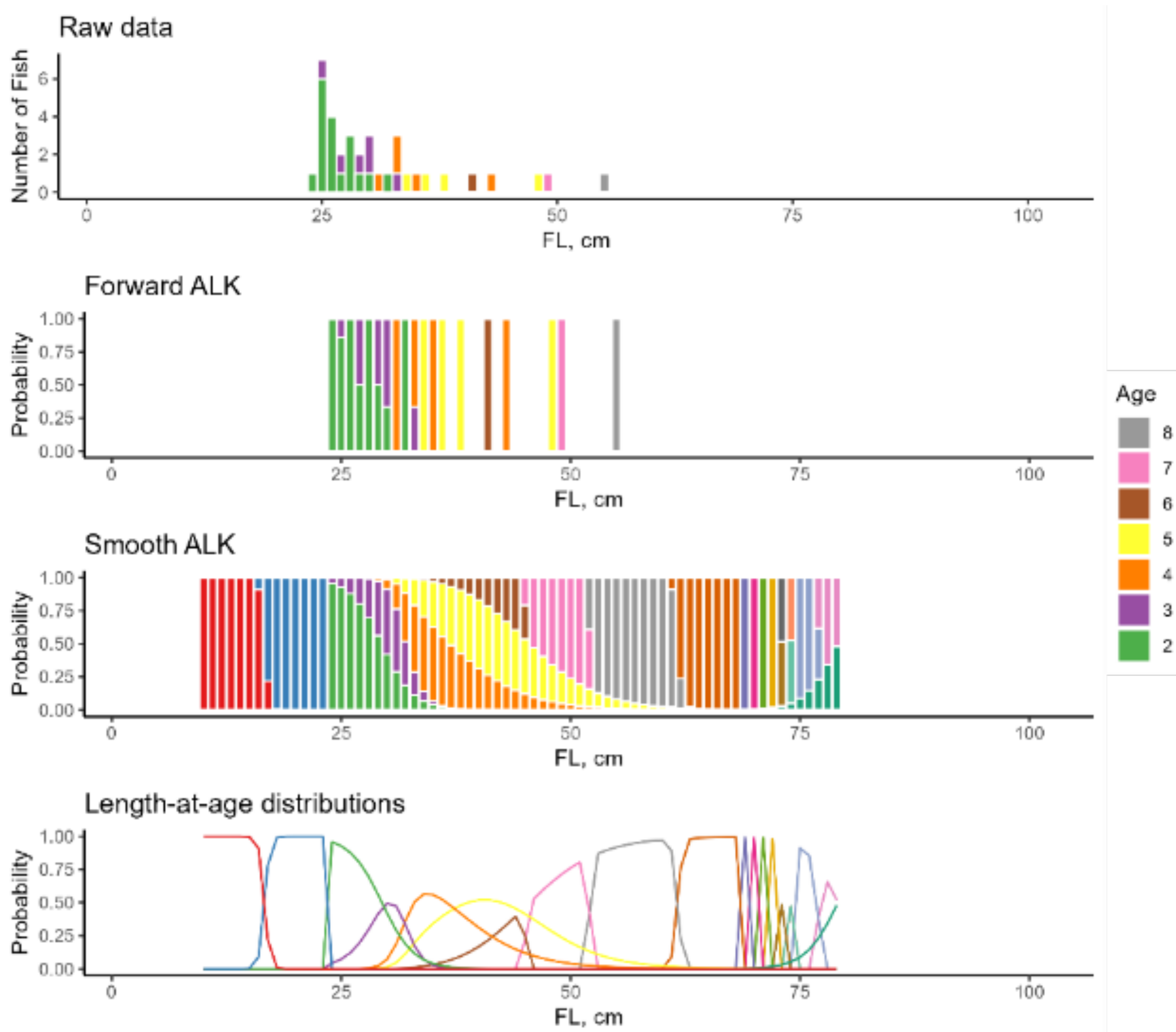

Figure 10. Age data and derived ALKs for 1997 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

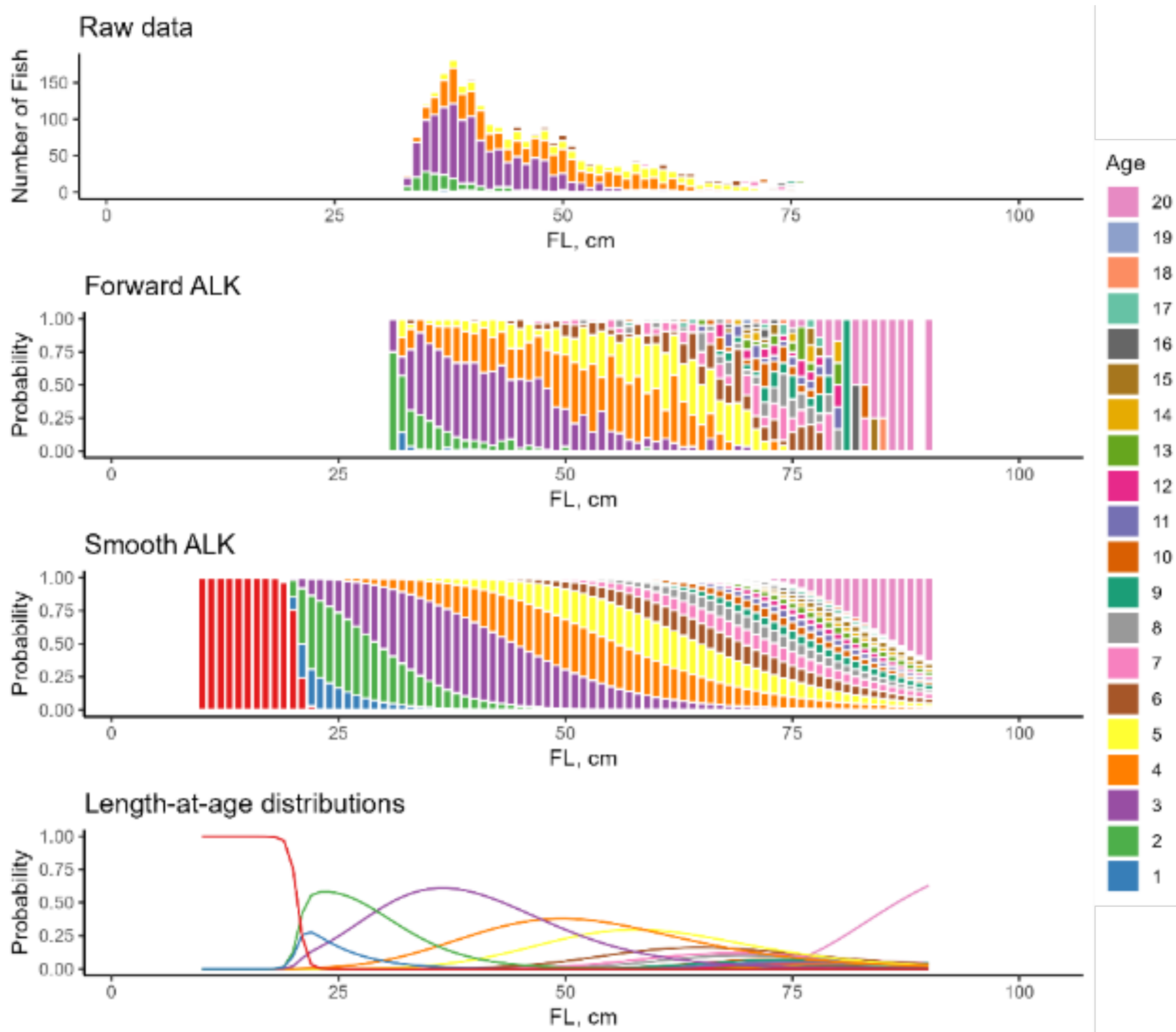

Figure 11. Age data and derived ALKs for 1998 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

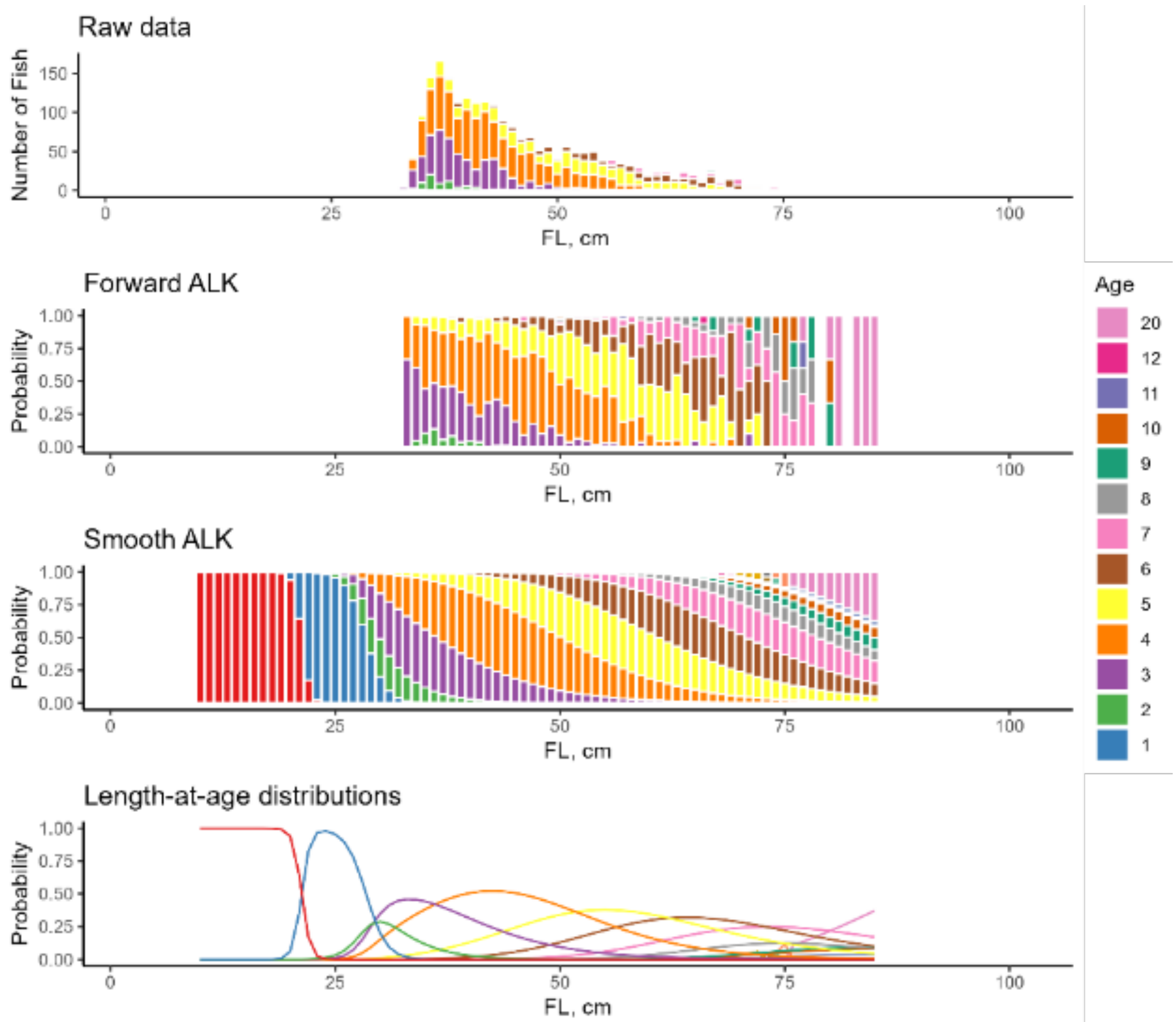

Figure 12. Age data and derived ALKs for 1999 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

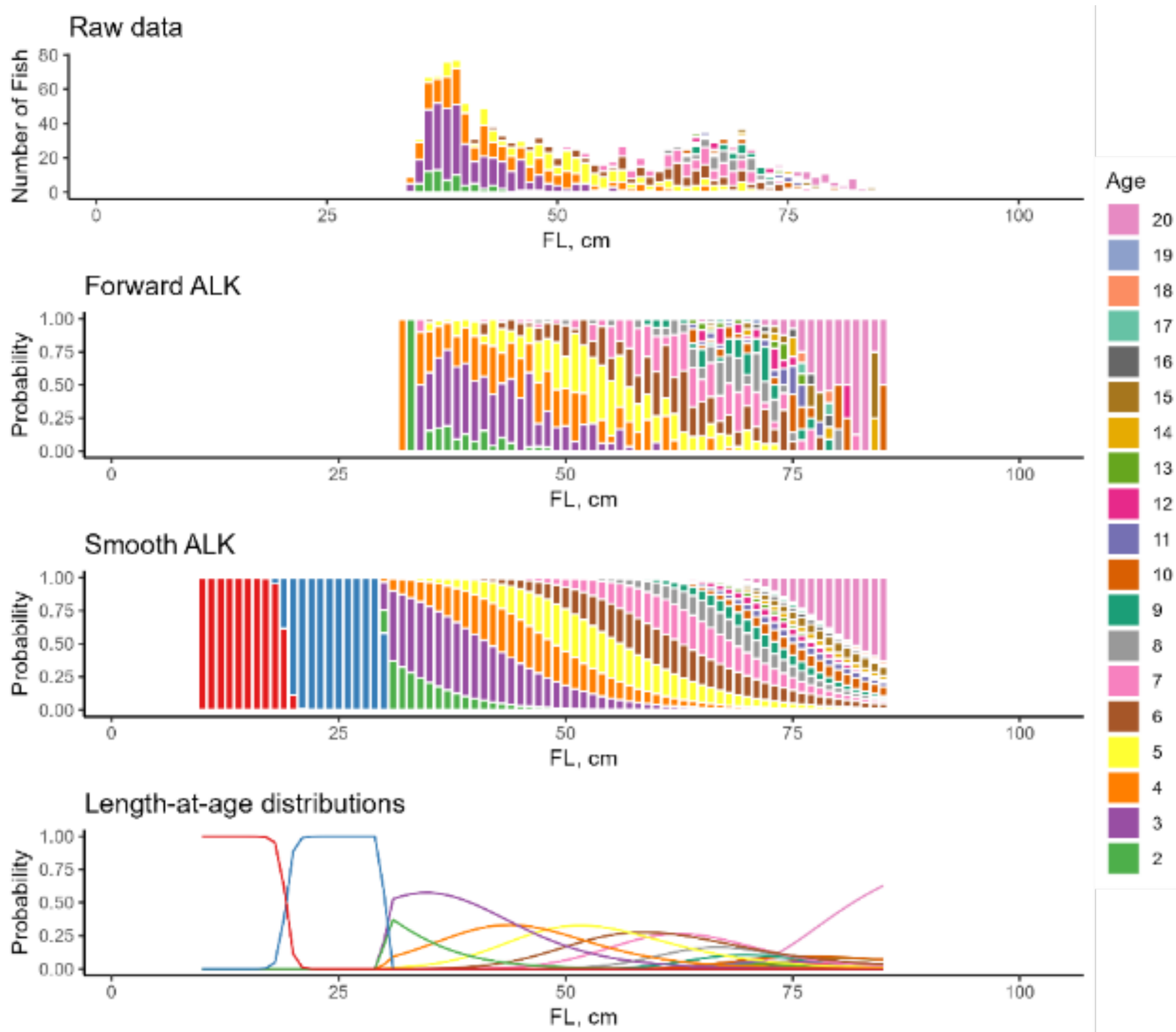

Figure 13. Age data and derived ALKs for 2000 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

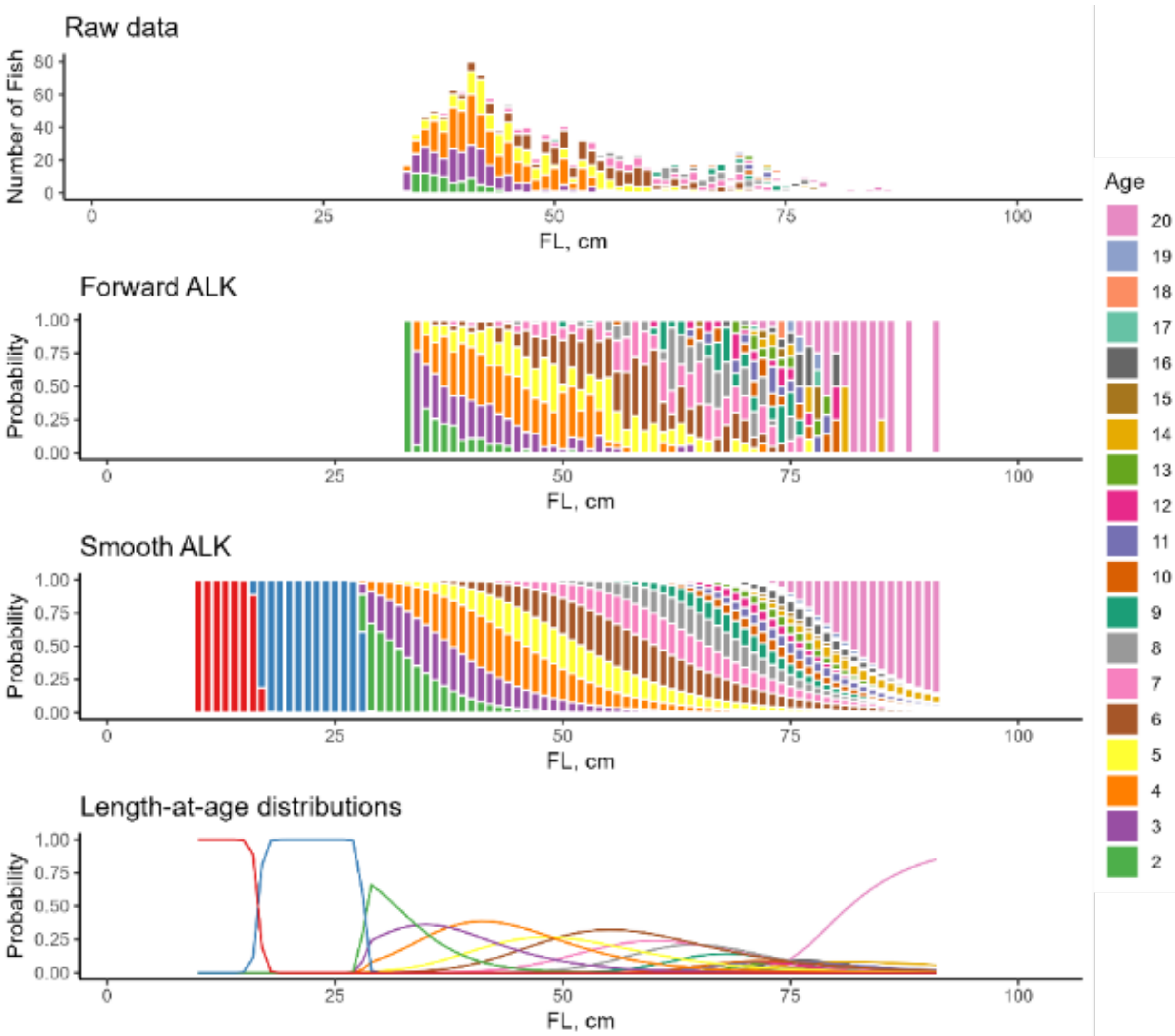

Figure 14. Age data and derived ALKs for 2001 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

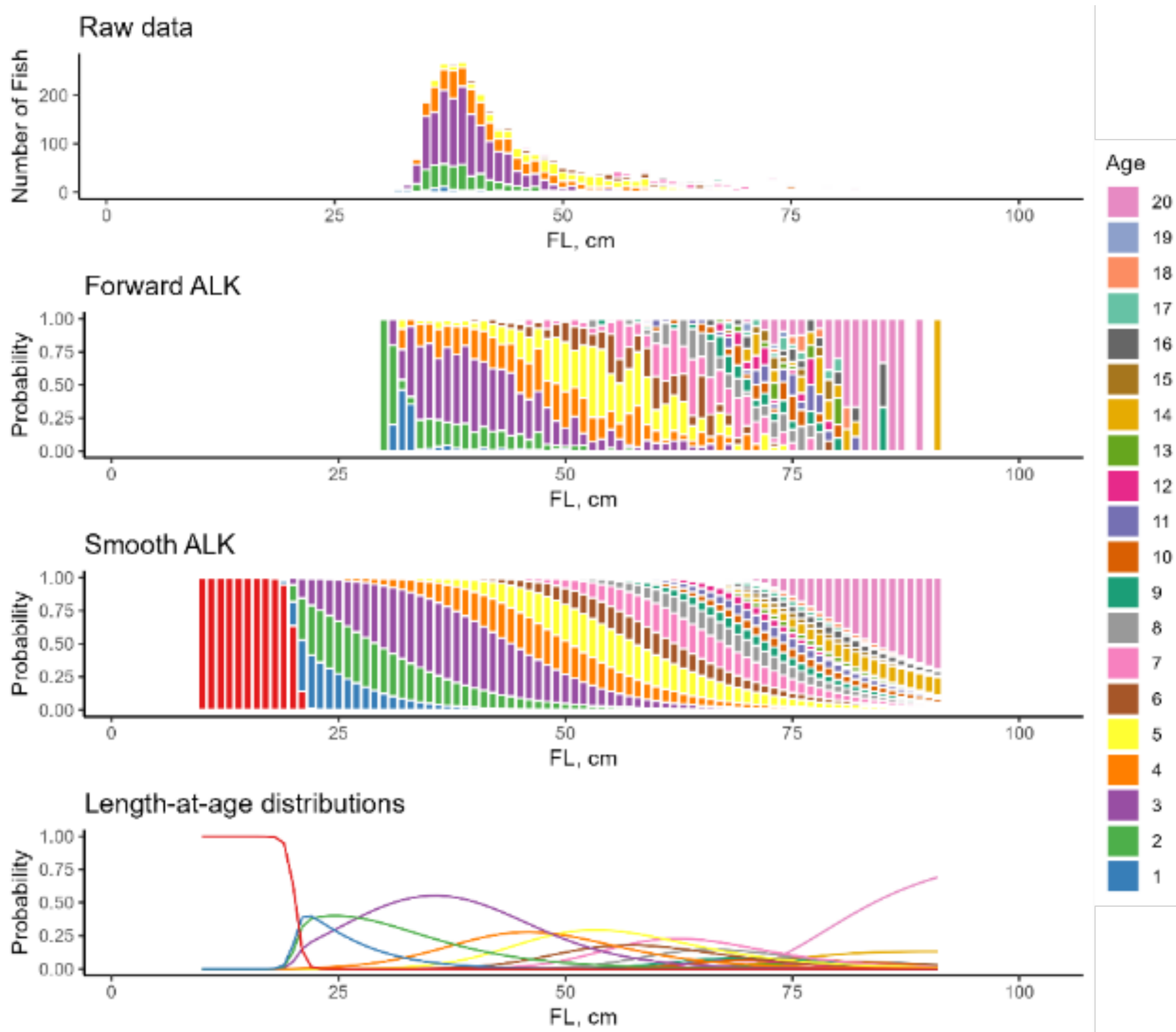

Figure 15. Age data and derived ALKs for 2002 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

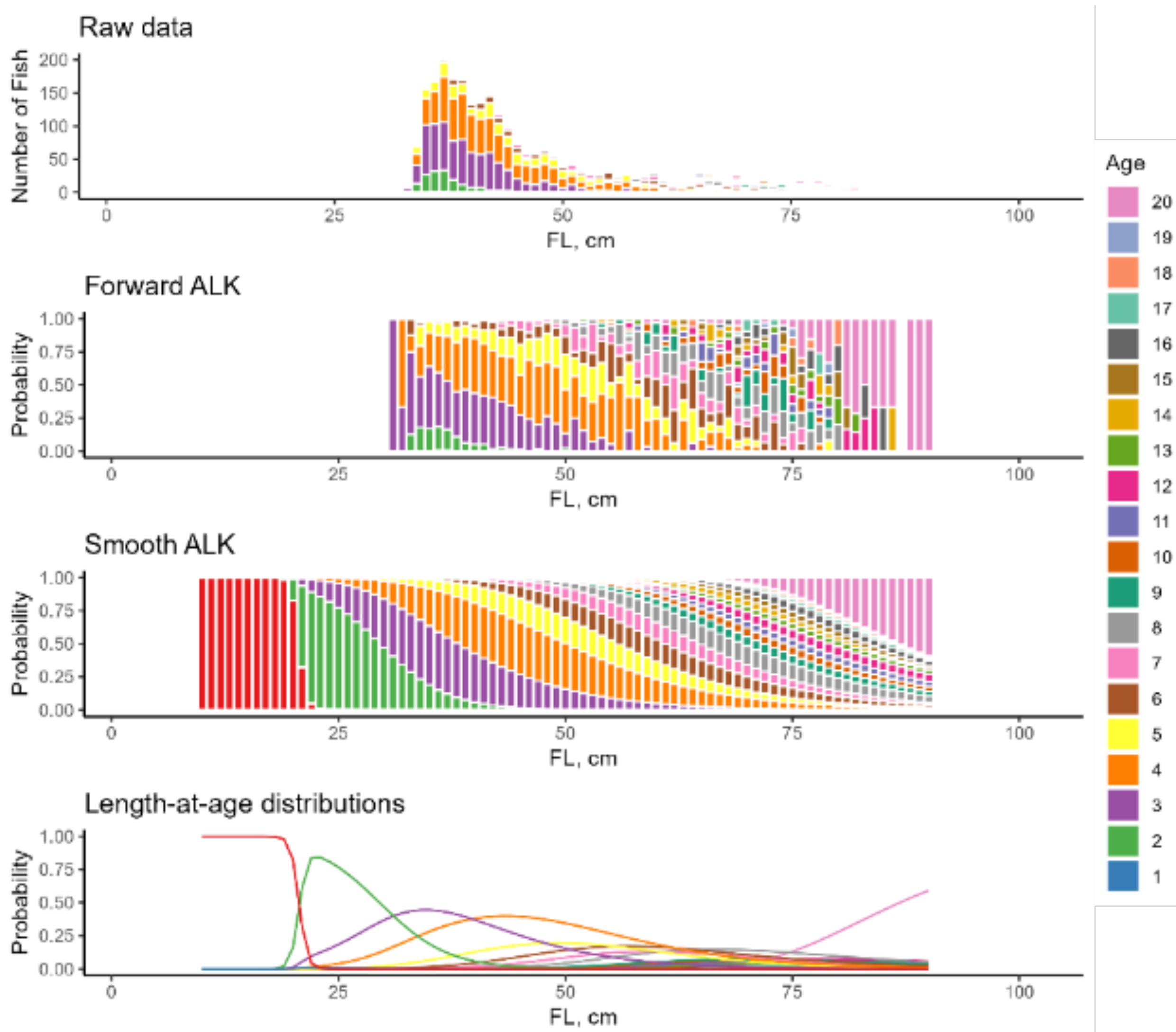

Figure 16. Age data and derived ALKs for 2003 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

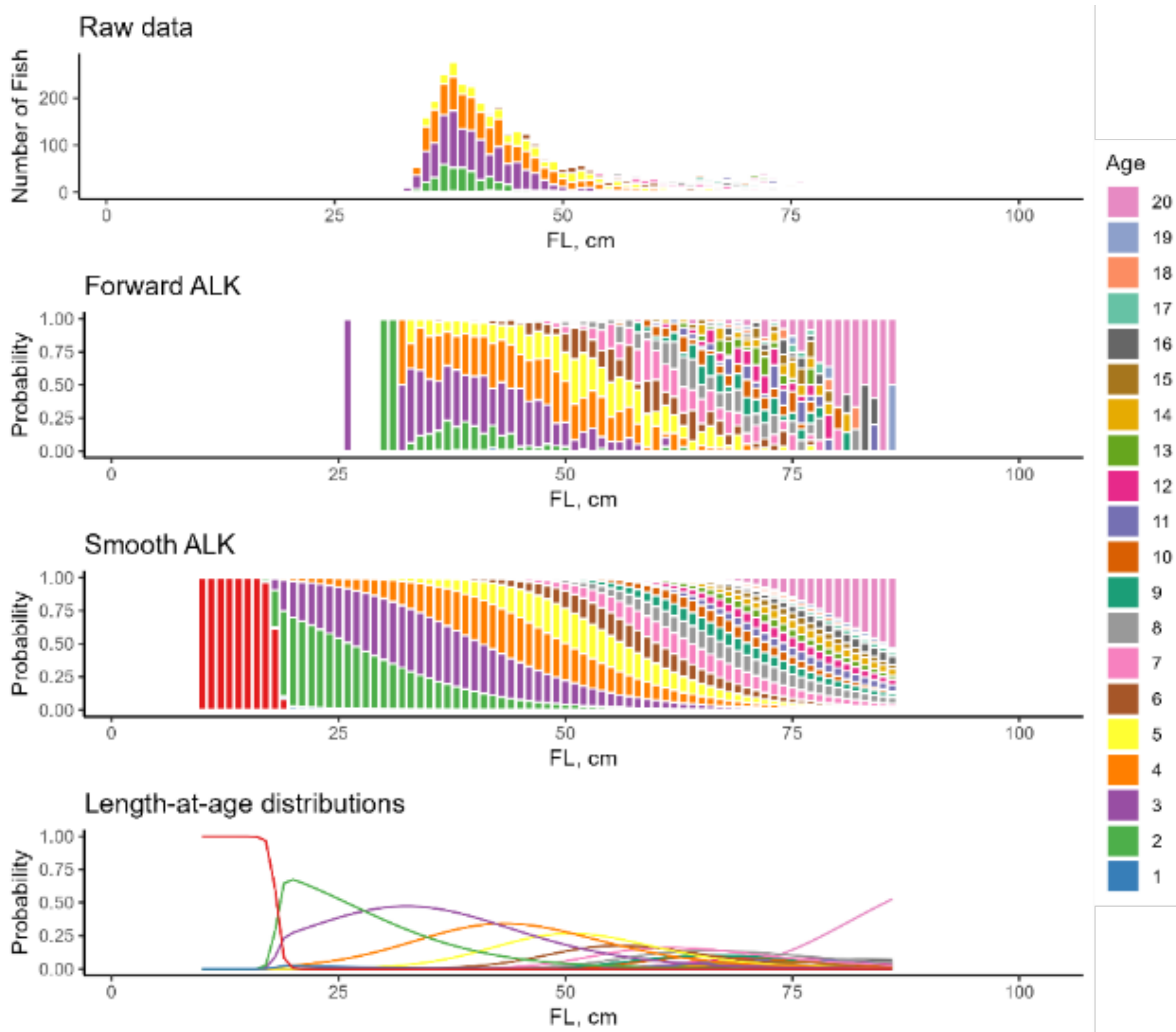

Figure 17. Age data and derived ALKs for 2004 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

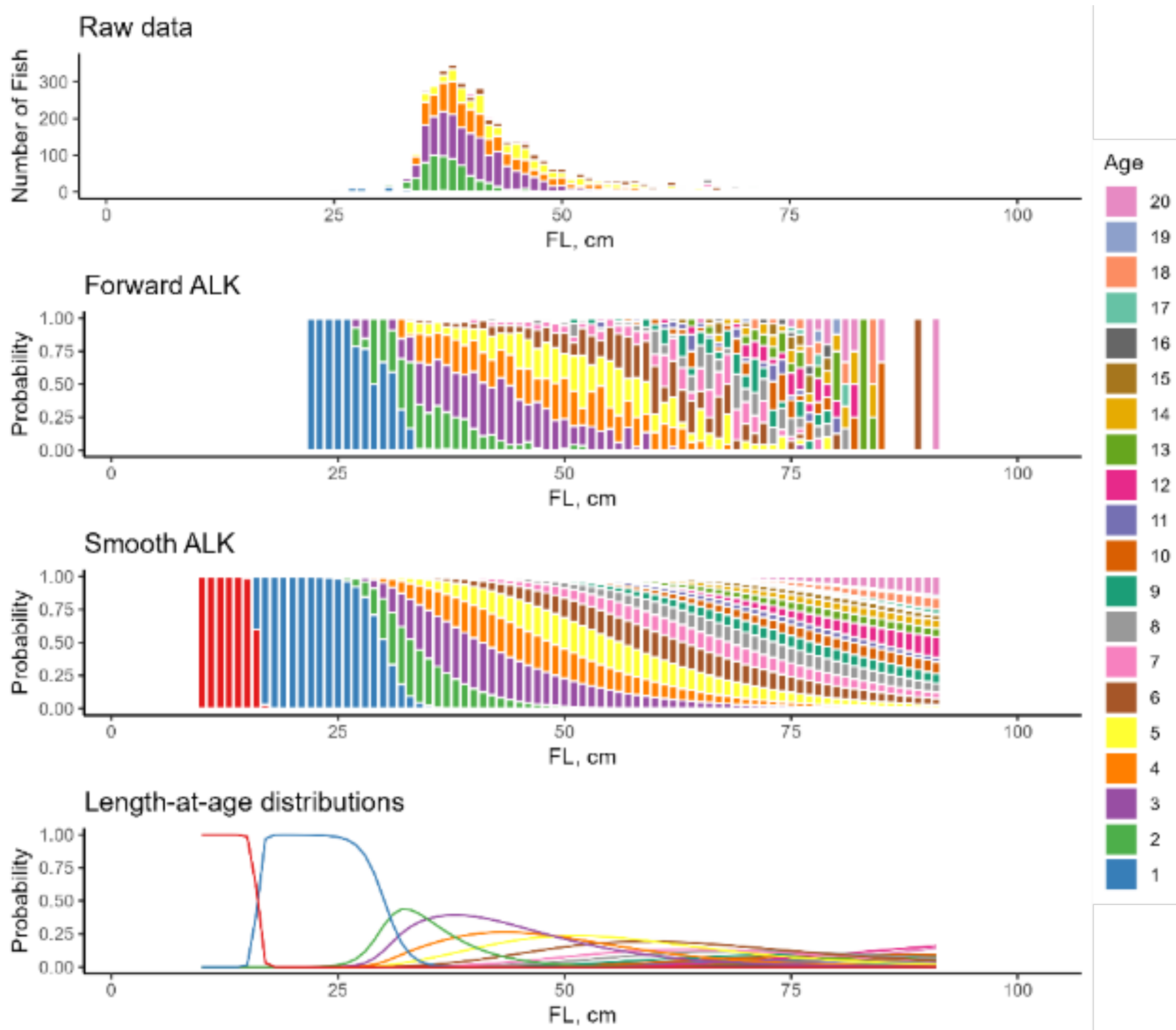

Figure 18. Age data and derived ALKs for 2005 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

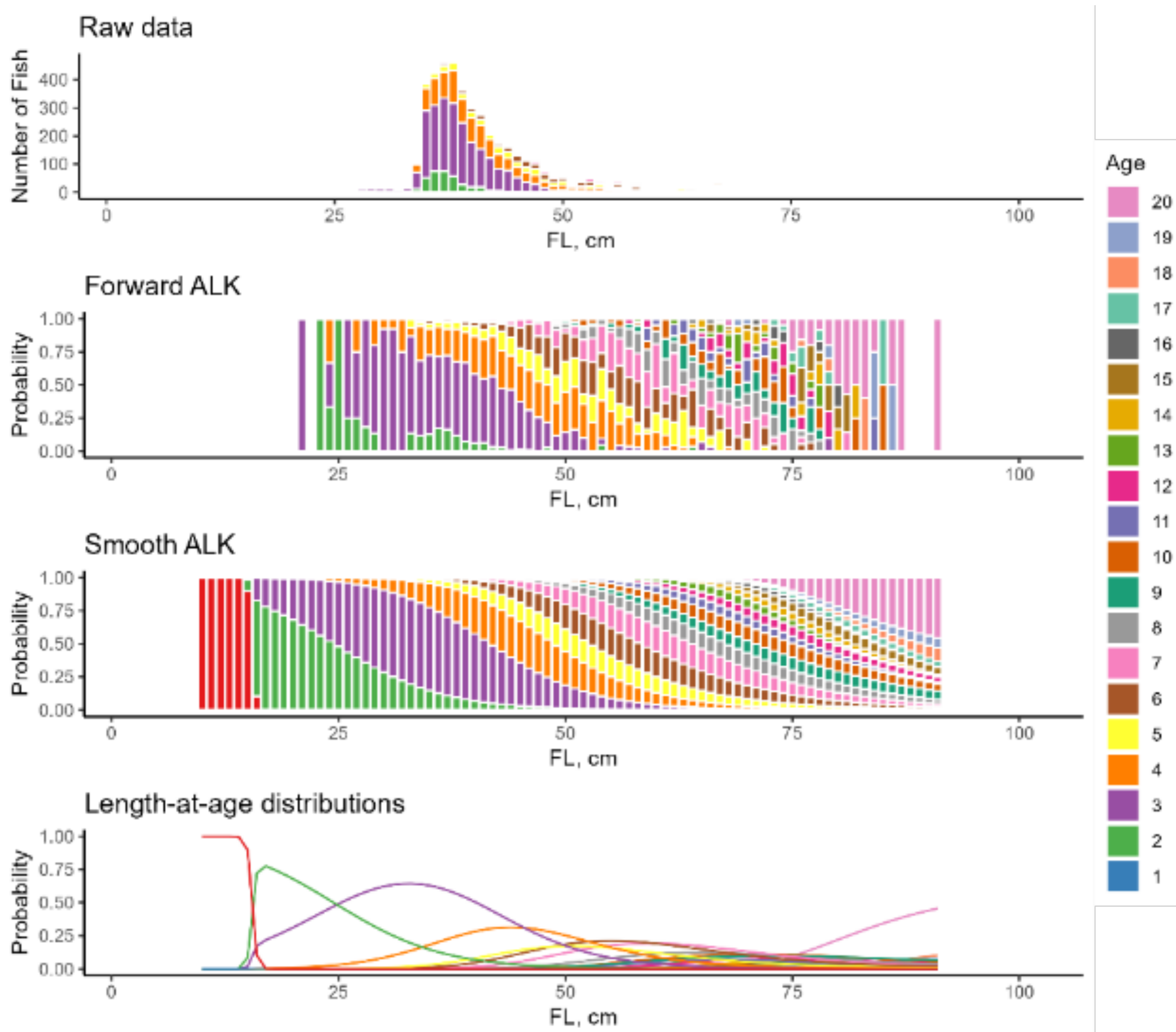

Figure 19. Age data and derived ALKs for 2006 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

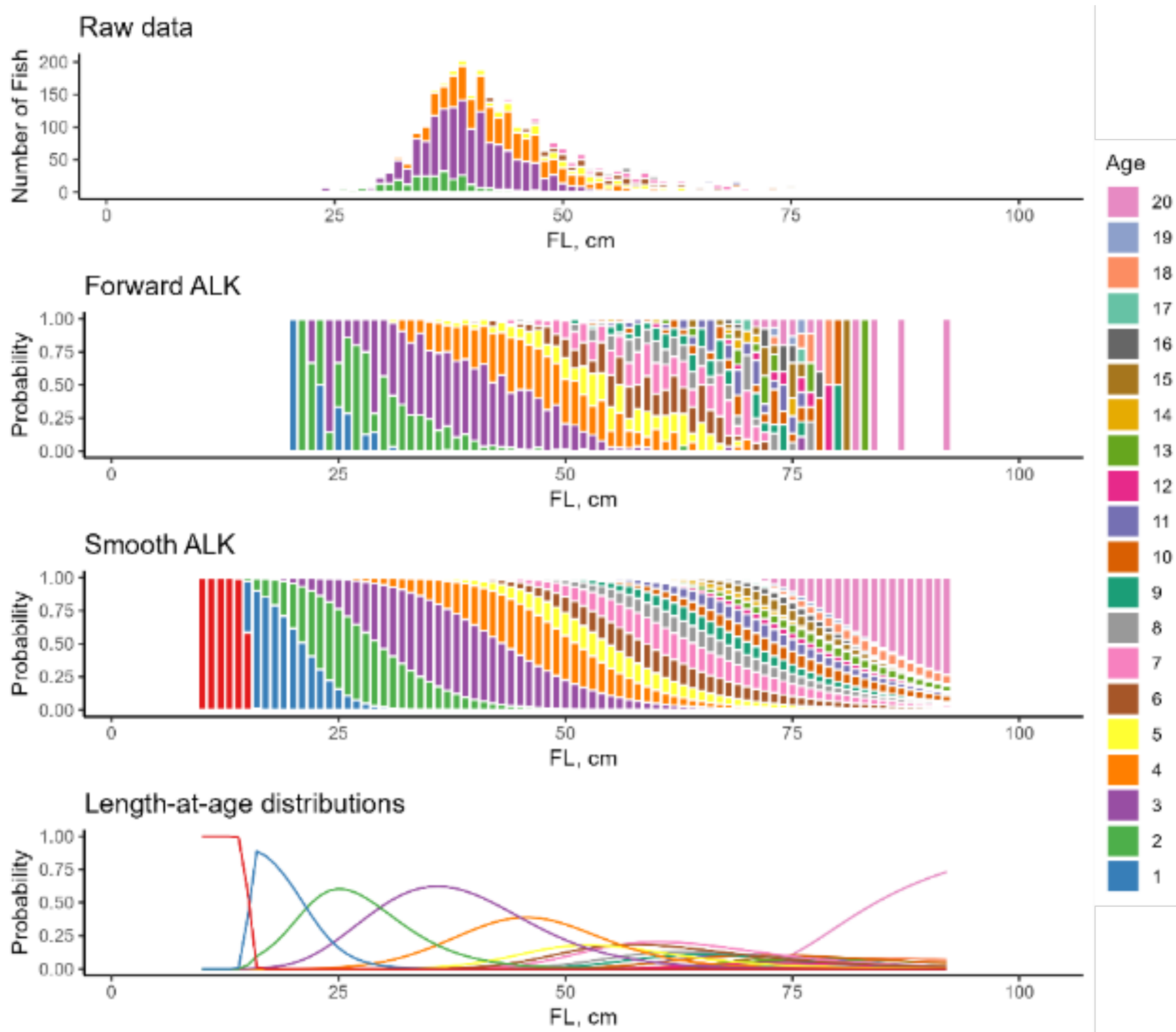

Figure 20. Age data and derived ALKs for 2007 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

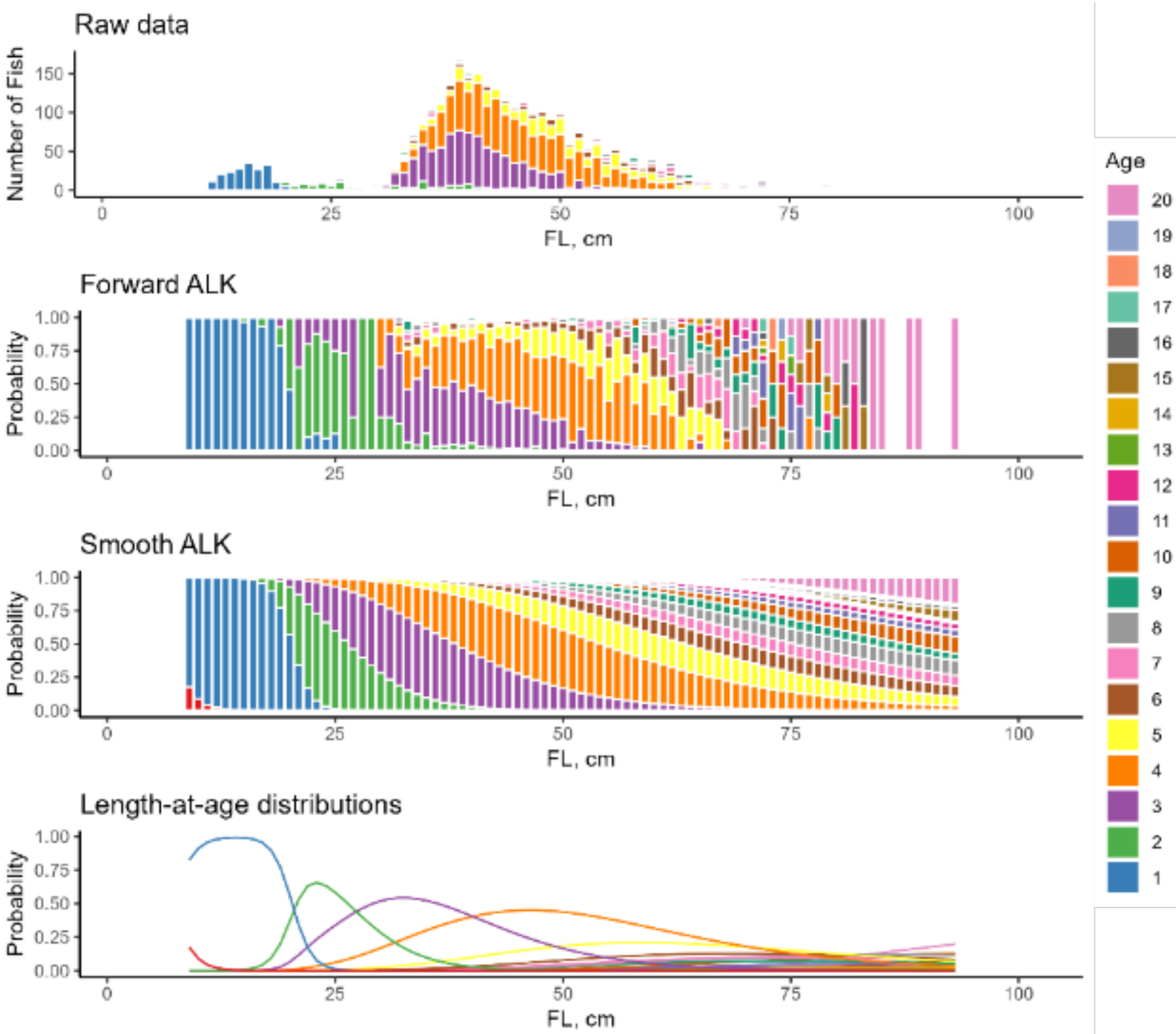

Figure 21. Age data and derived ALKs for 2008 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

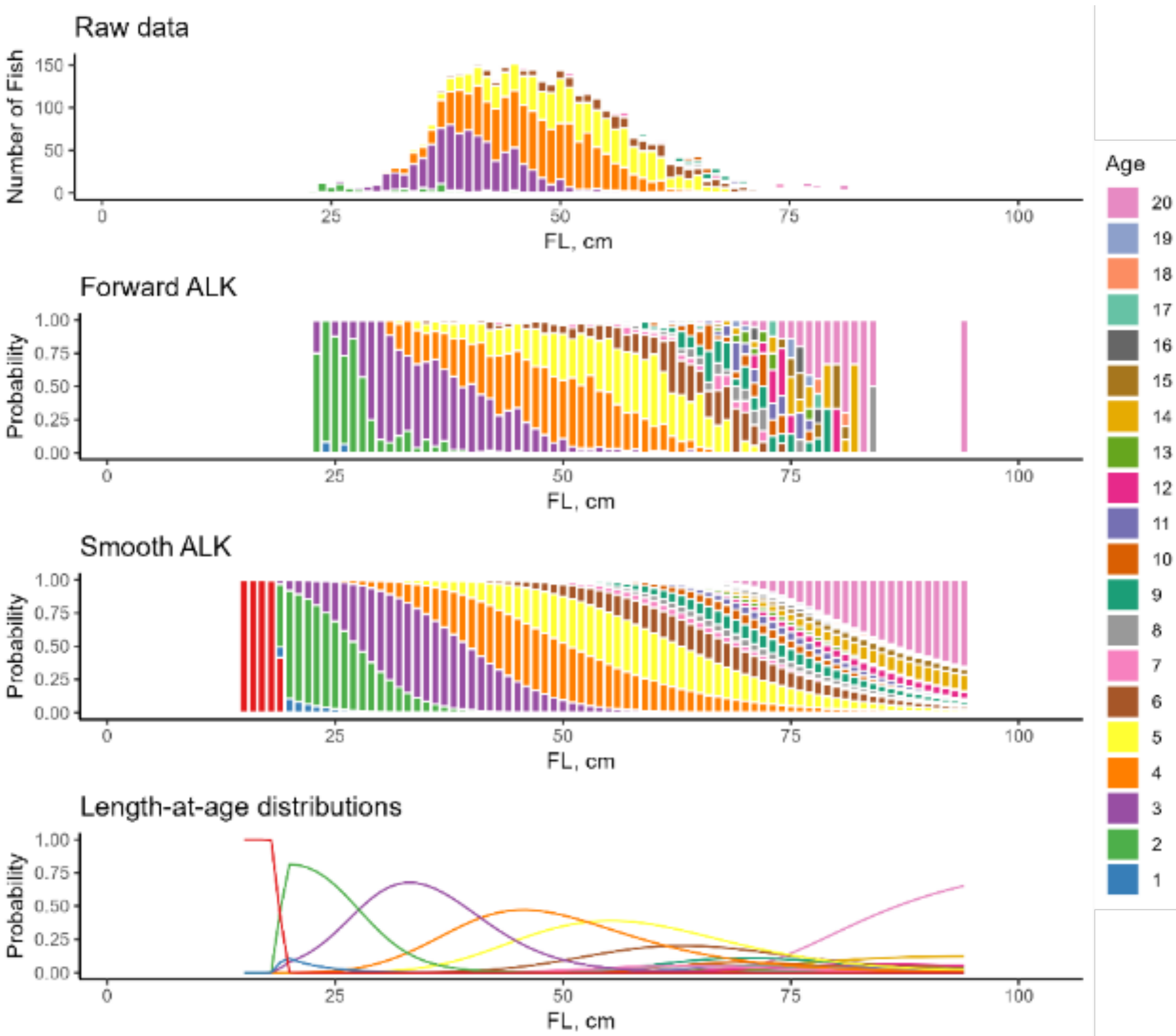

Figure 22. Age data and derived ALKs for 2009 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

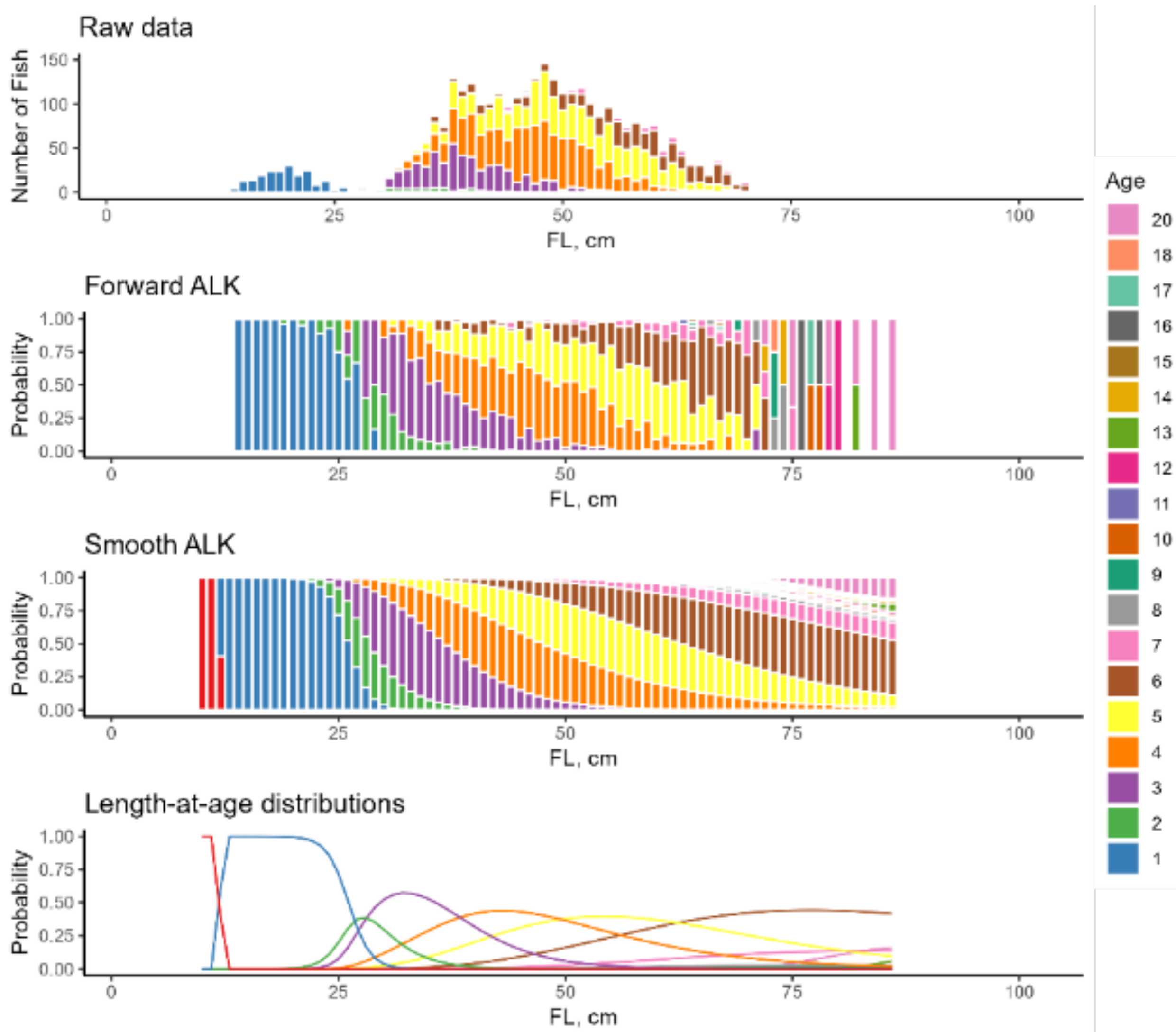

Figure 23. Age data and derived ALKs for 2010 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

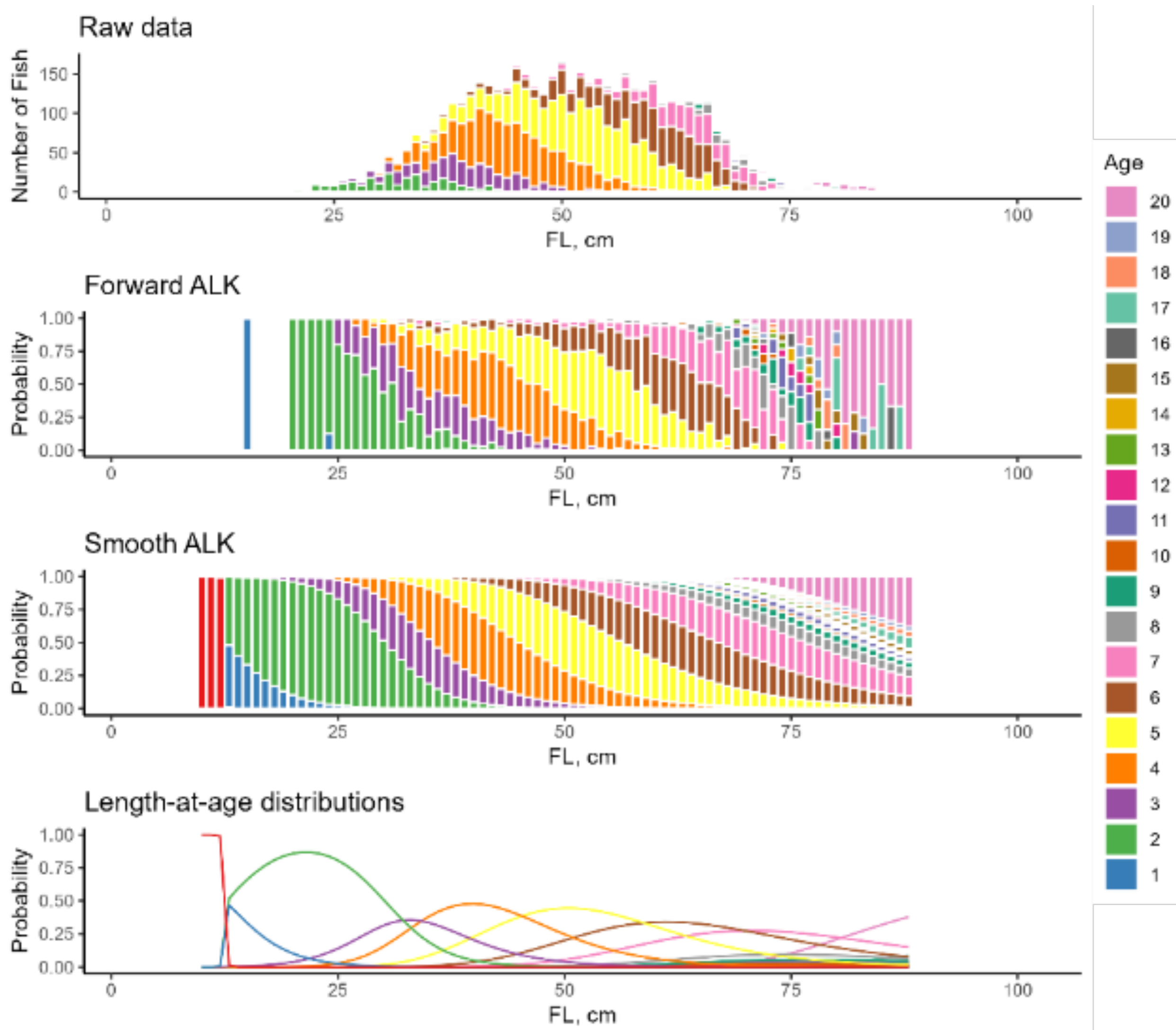

Figure 24. Age data and derived ALKs for 2011 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

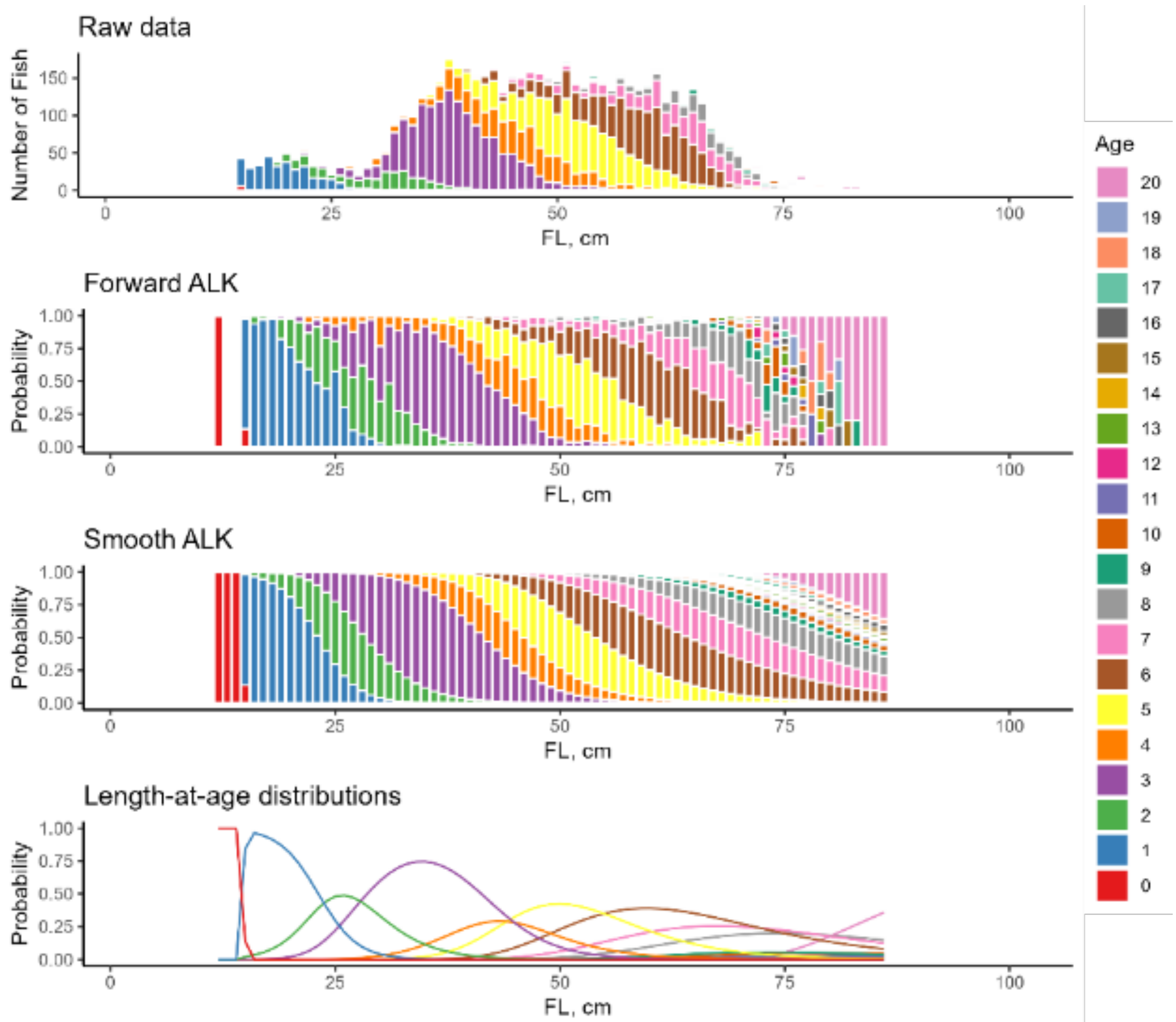

Figure 25. Age data and derived ALKs for 2012 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

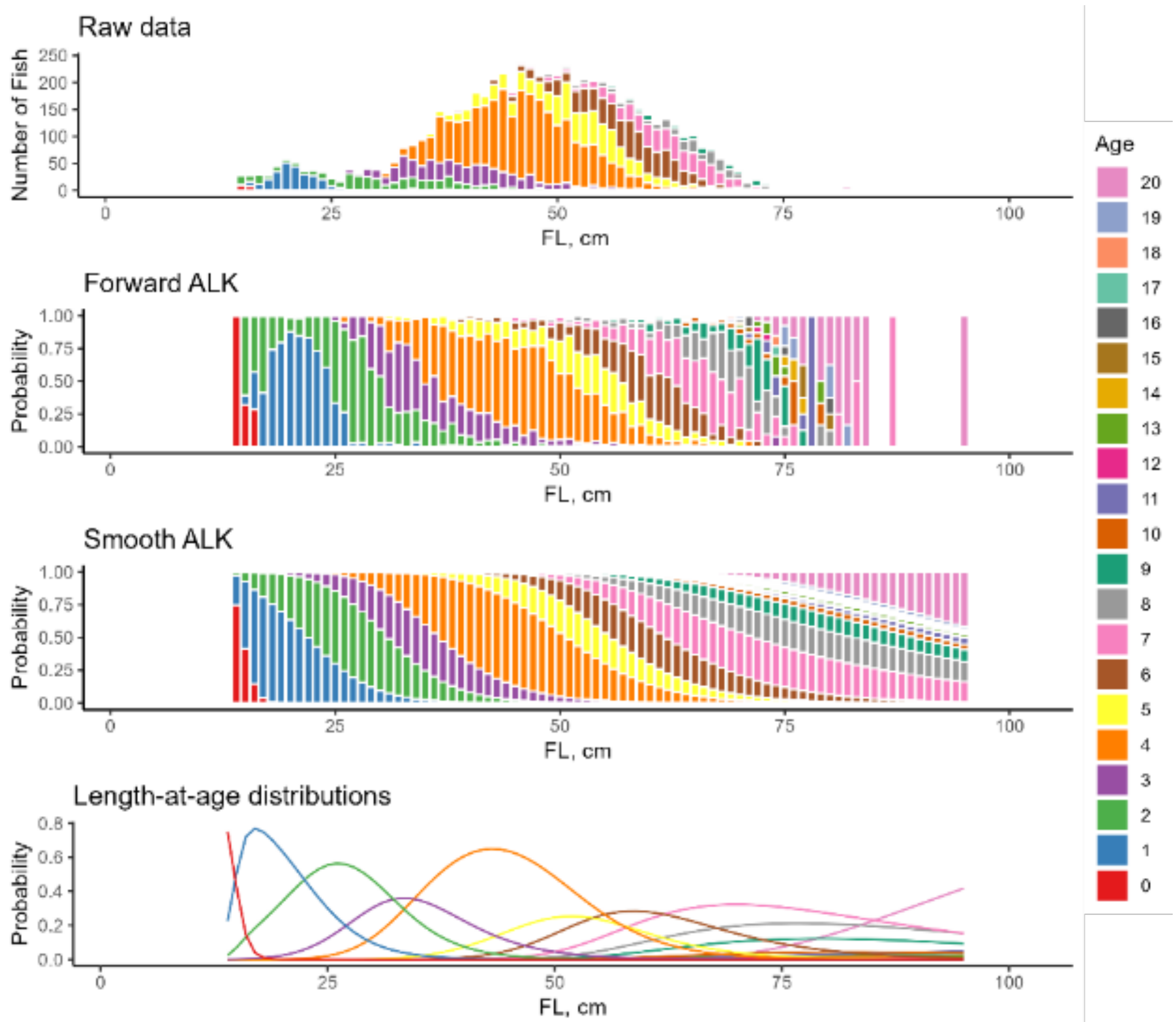

Figure 26. Age data and derived ALKs for 2013 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

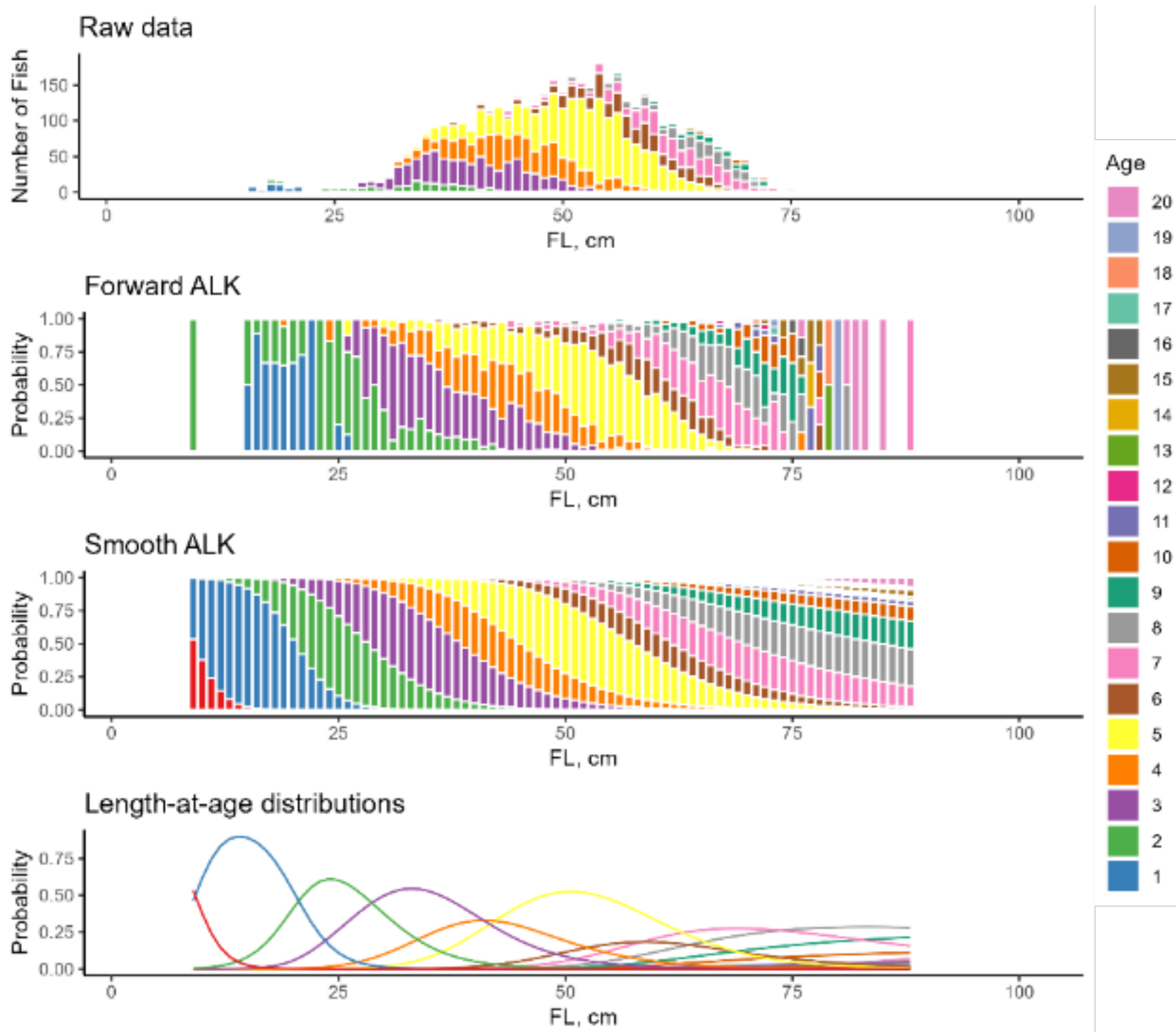

Figure 27. Age data and derived ALKs for 2014 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

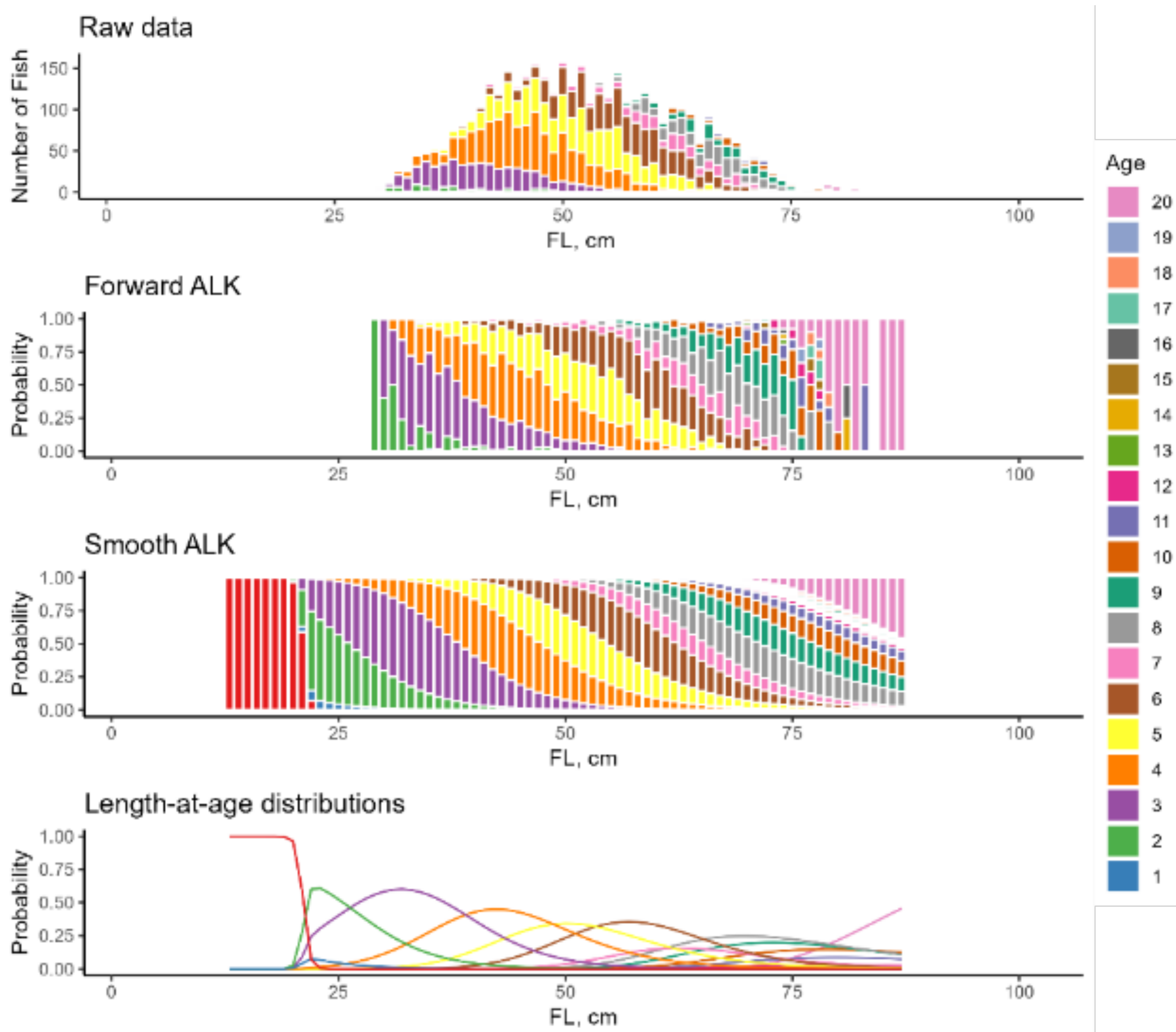

Figure 28. Age data and derived ALKs for 2015 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

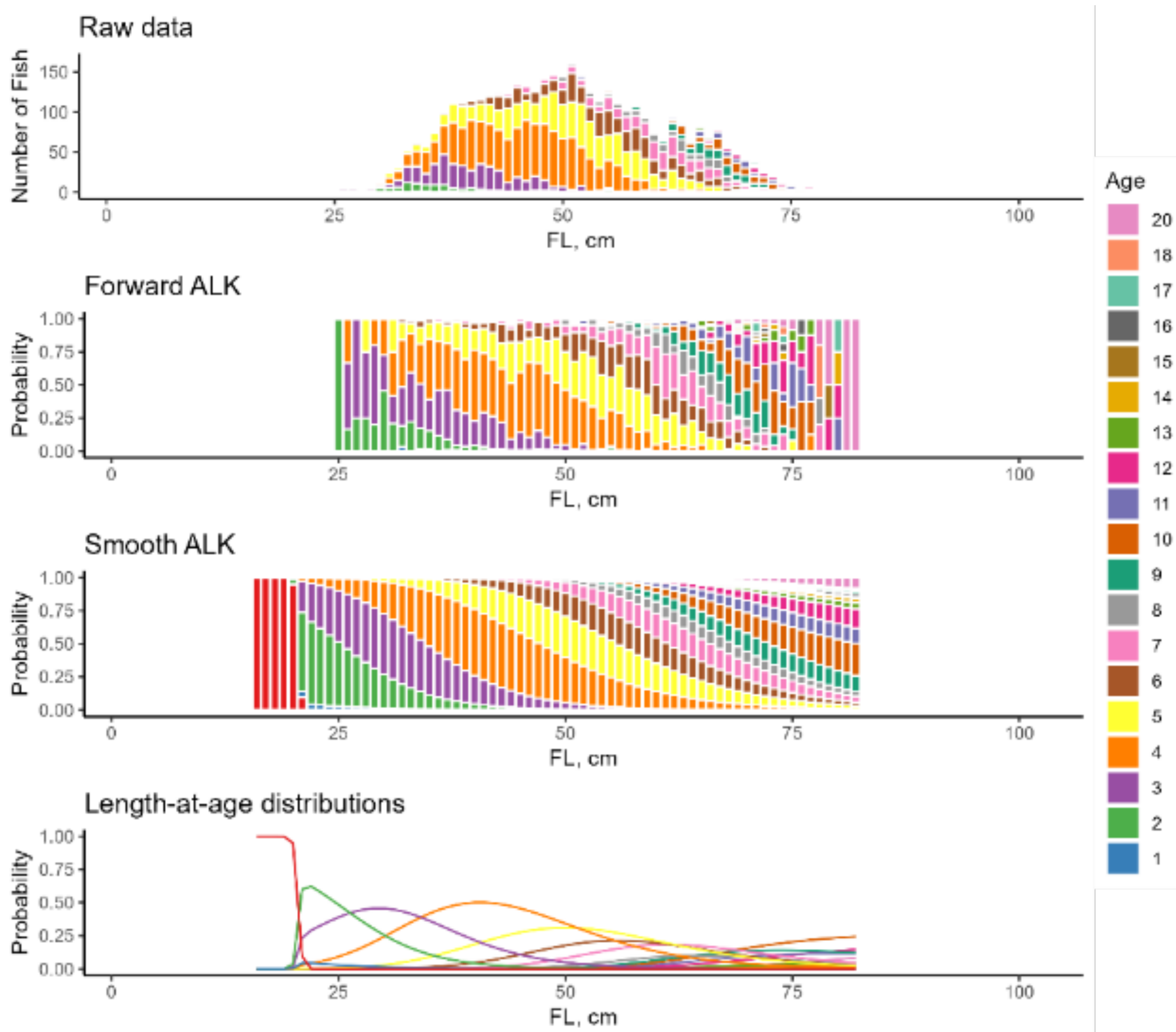

Figure 29. Age data and derived ALKs for 2016 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

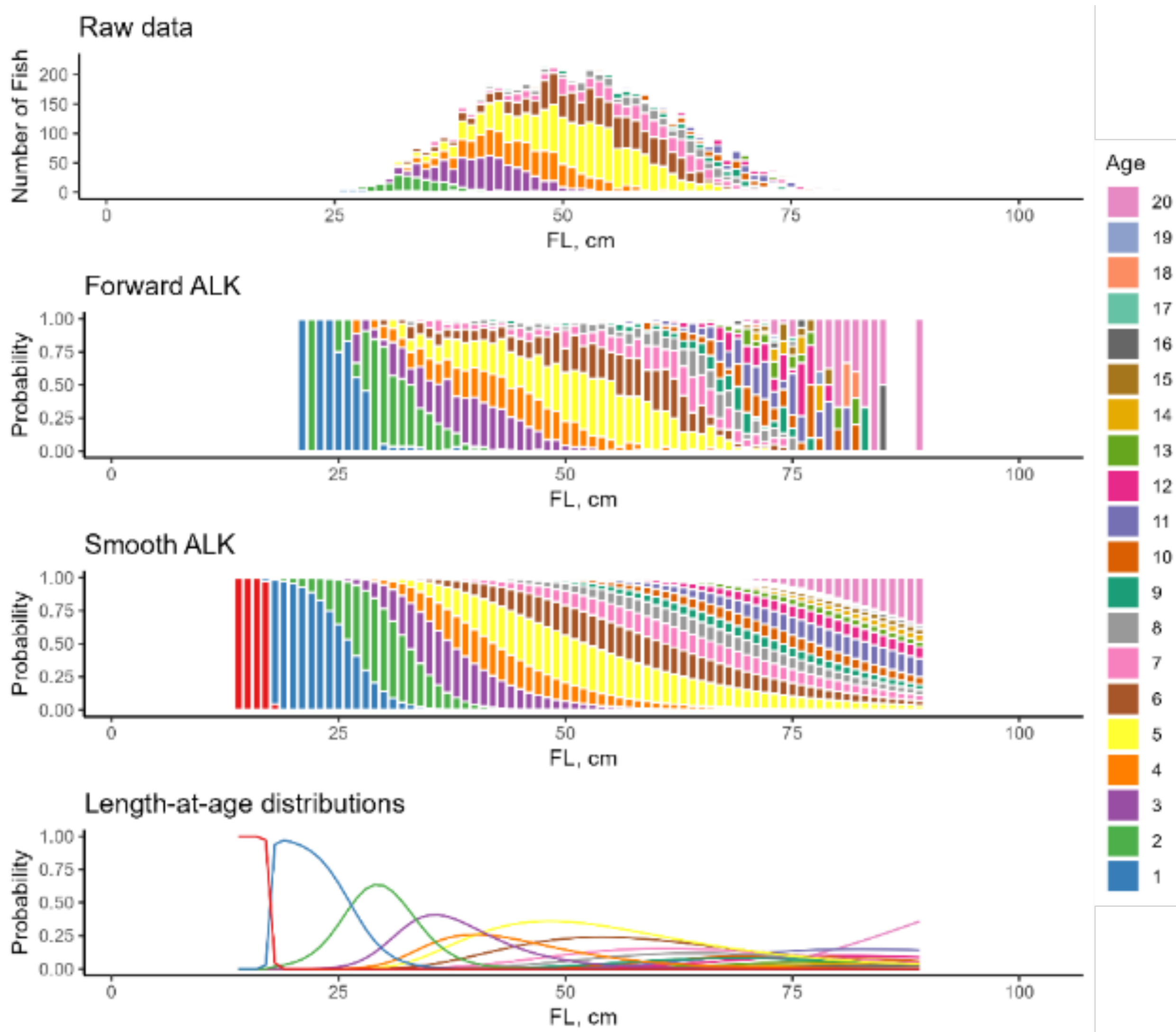

Figure 30. Age data and derived ALKs for 2017 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

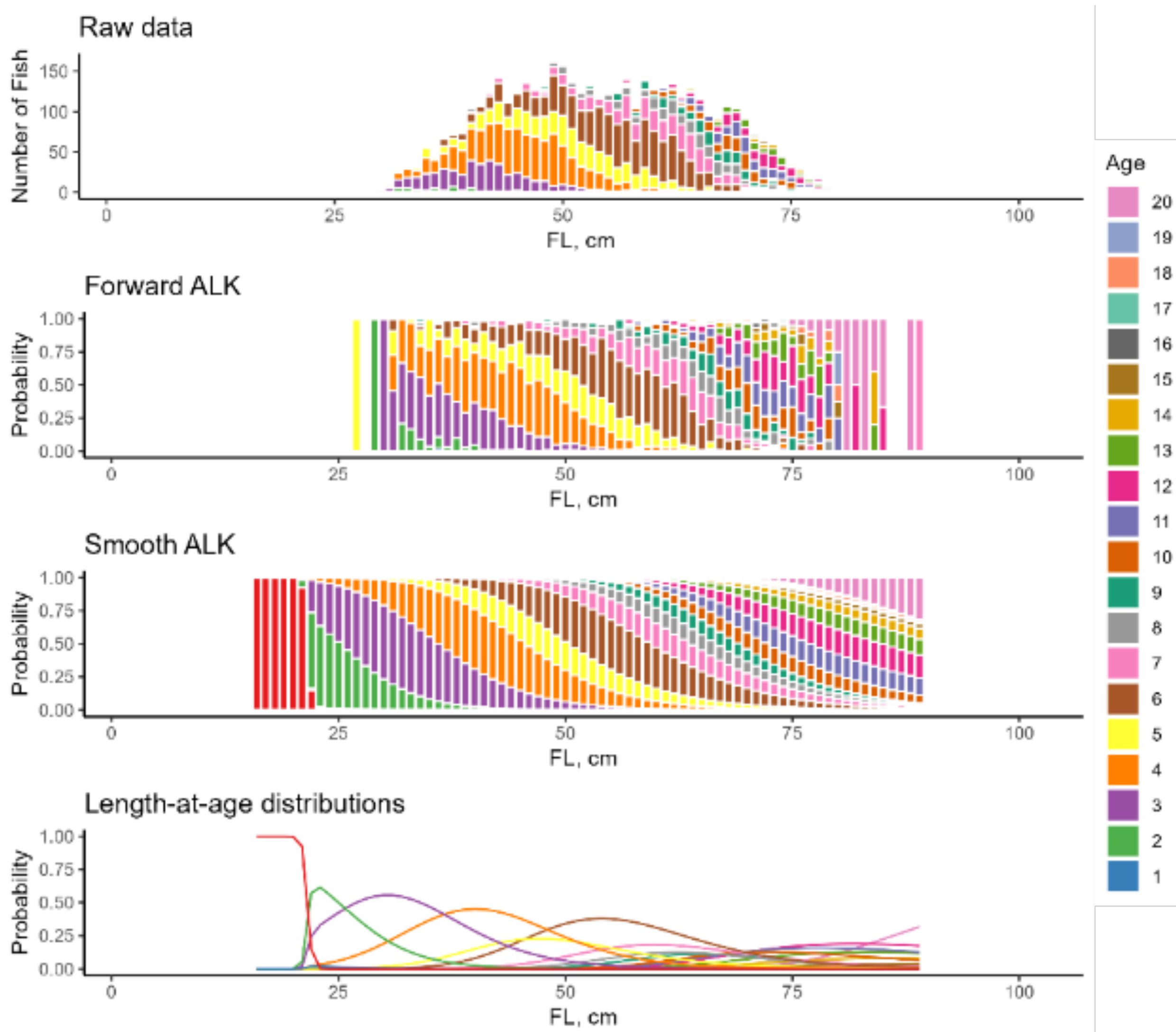

Figure 31. Age data and derived ALKs for 2018 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

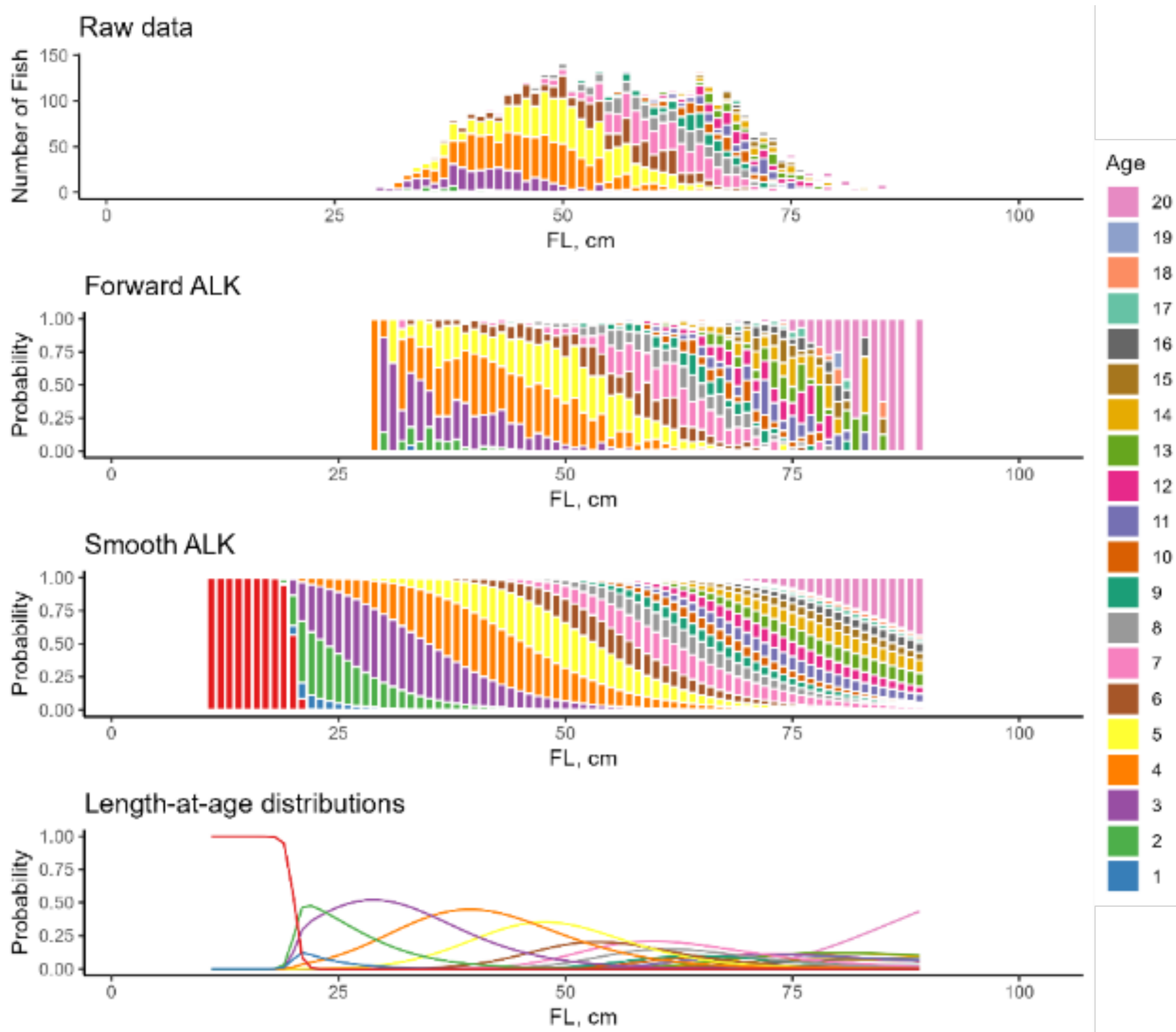

Figure 32. Age data and derived ALKs for 2019 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

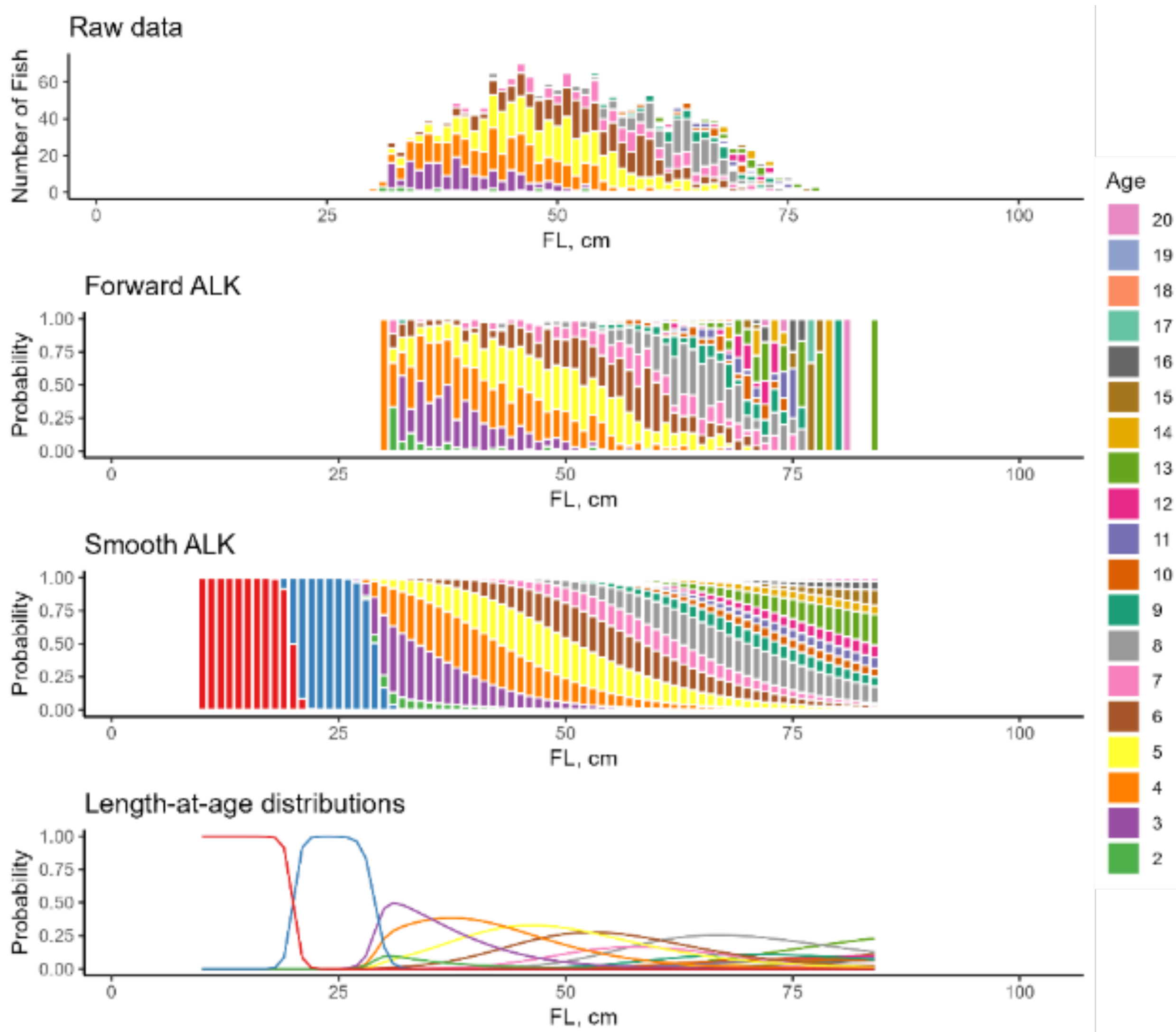

Figure 33. Age data and derived ALKs for 2020 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

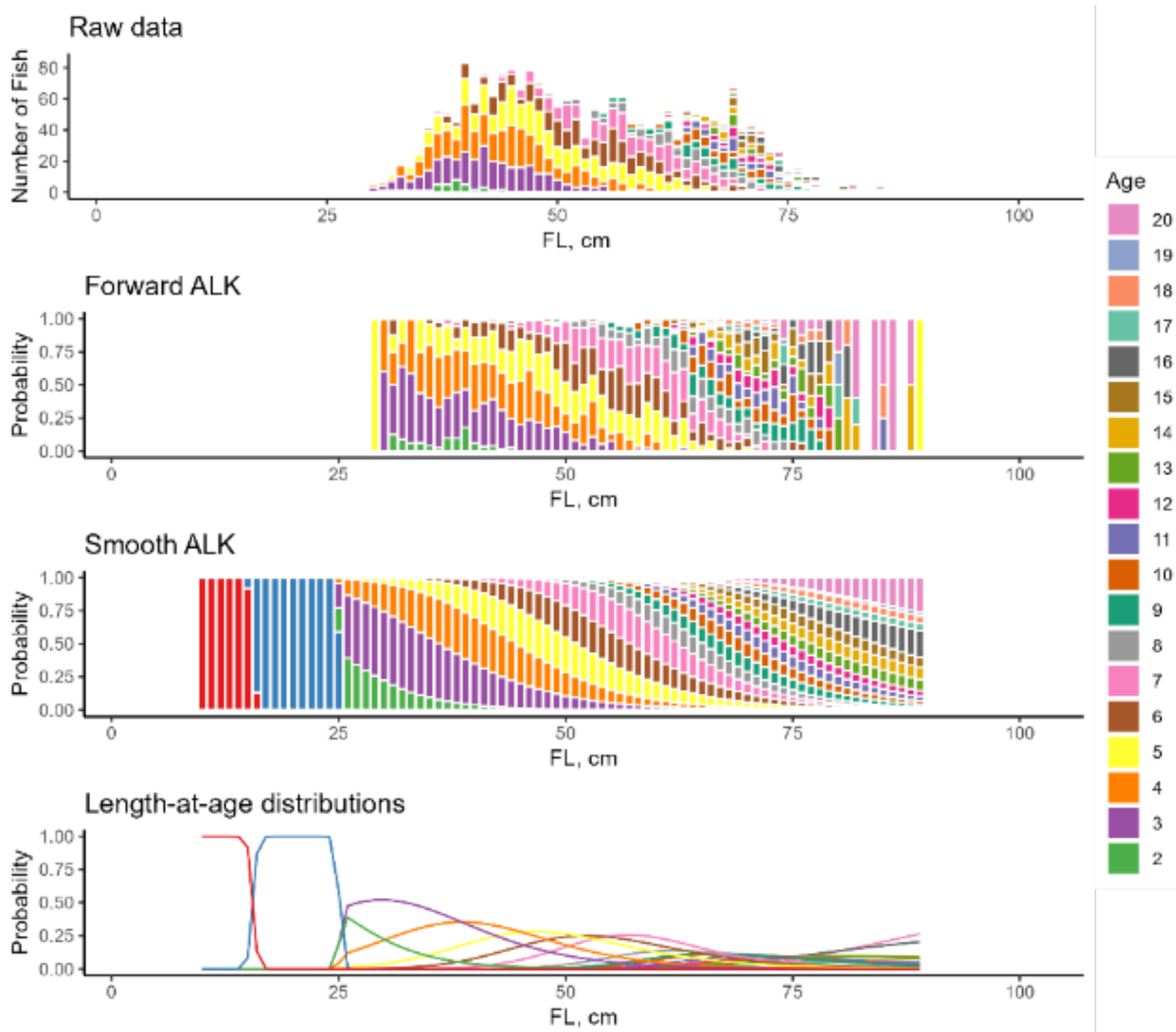

Figure 34. Age data and derived ALKs for 2021 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

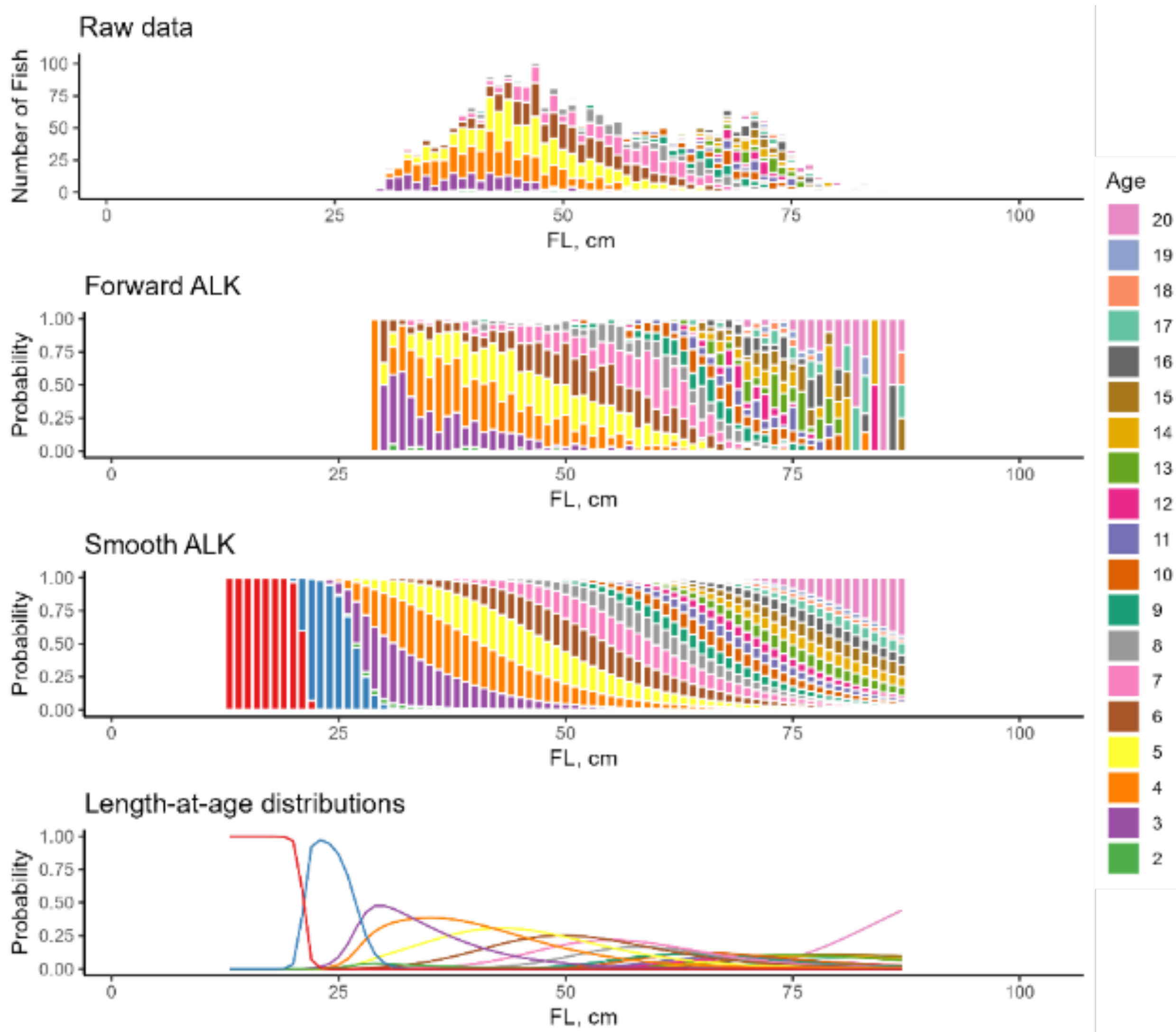

Figure 35. Age data and derived ALKs for 2022 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

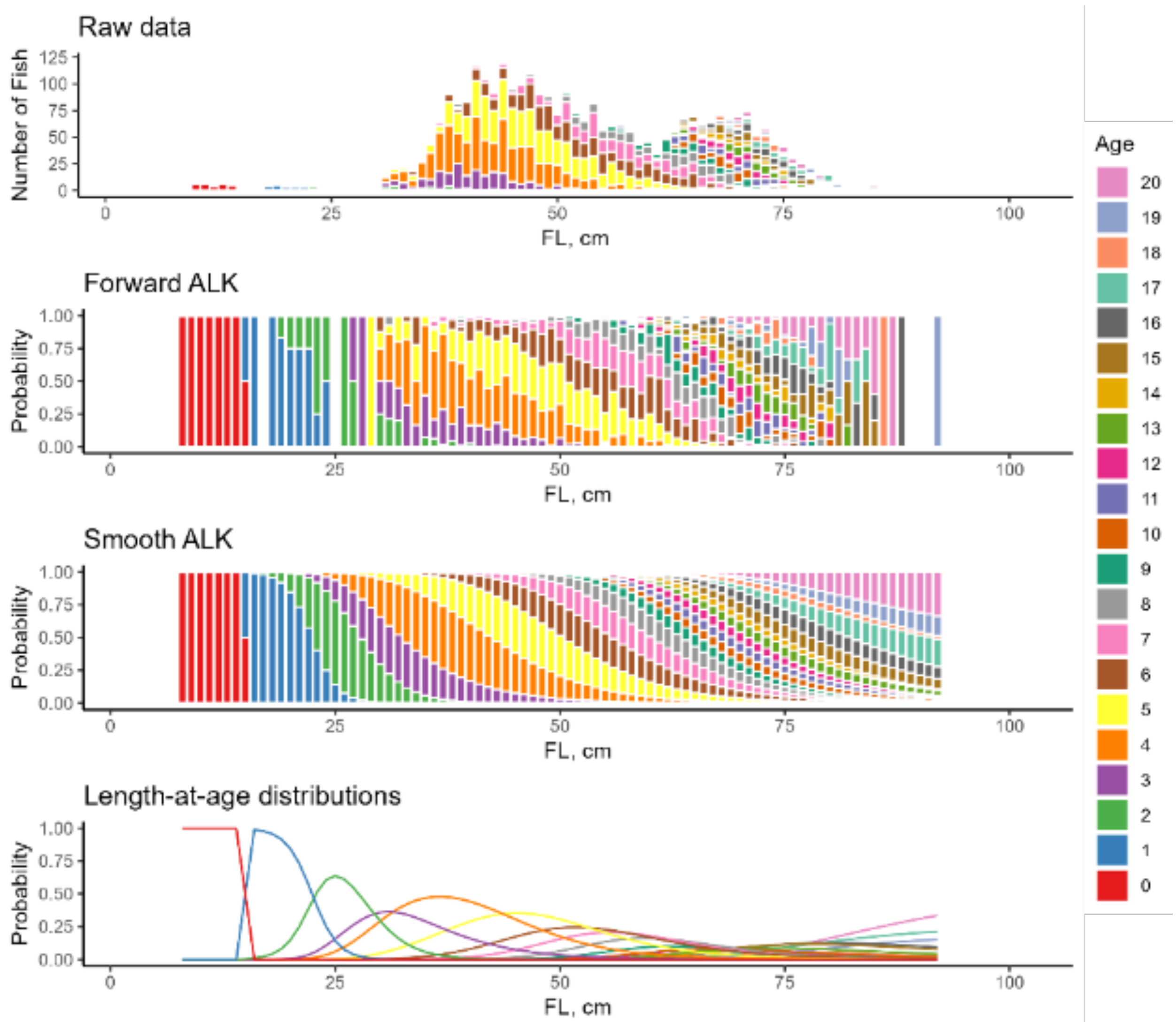

Figure 36. Age data and derived ALKs for 2023 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

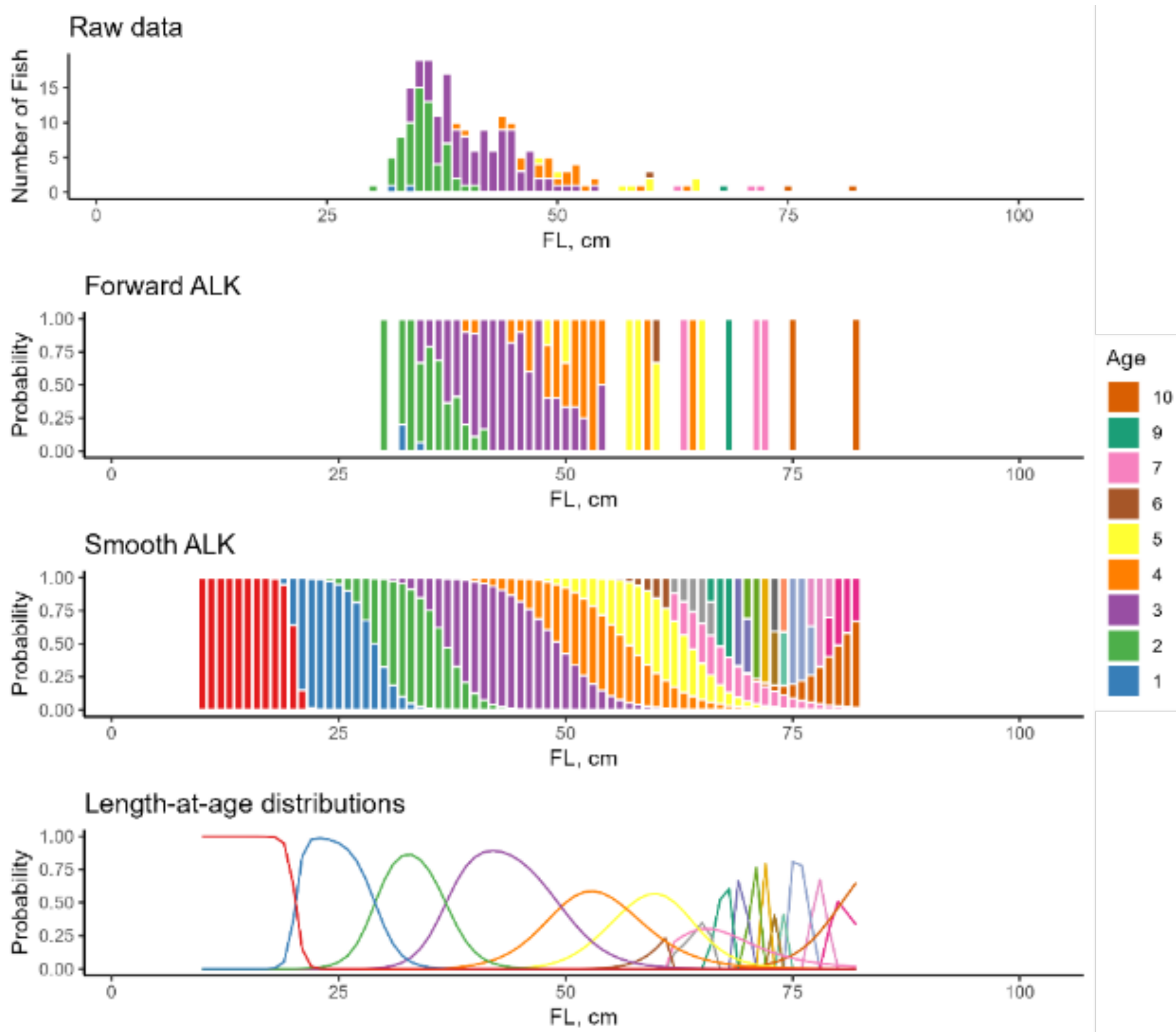

Figure 37. Age data and derived ALKs for 1996 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

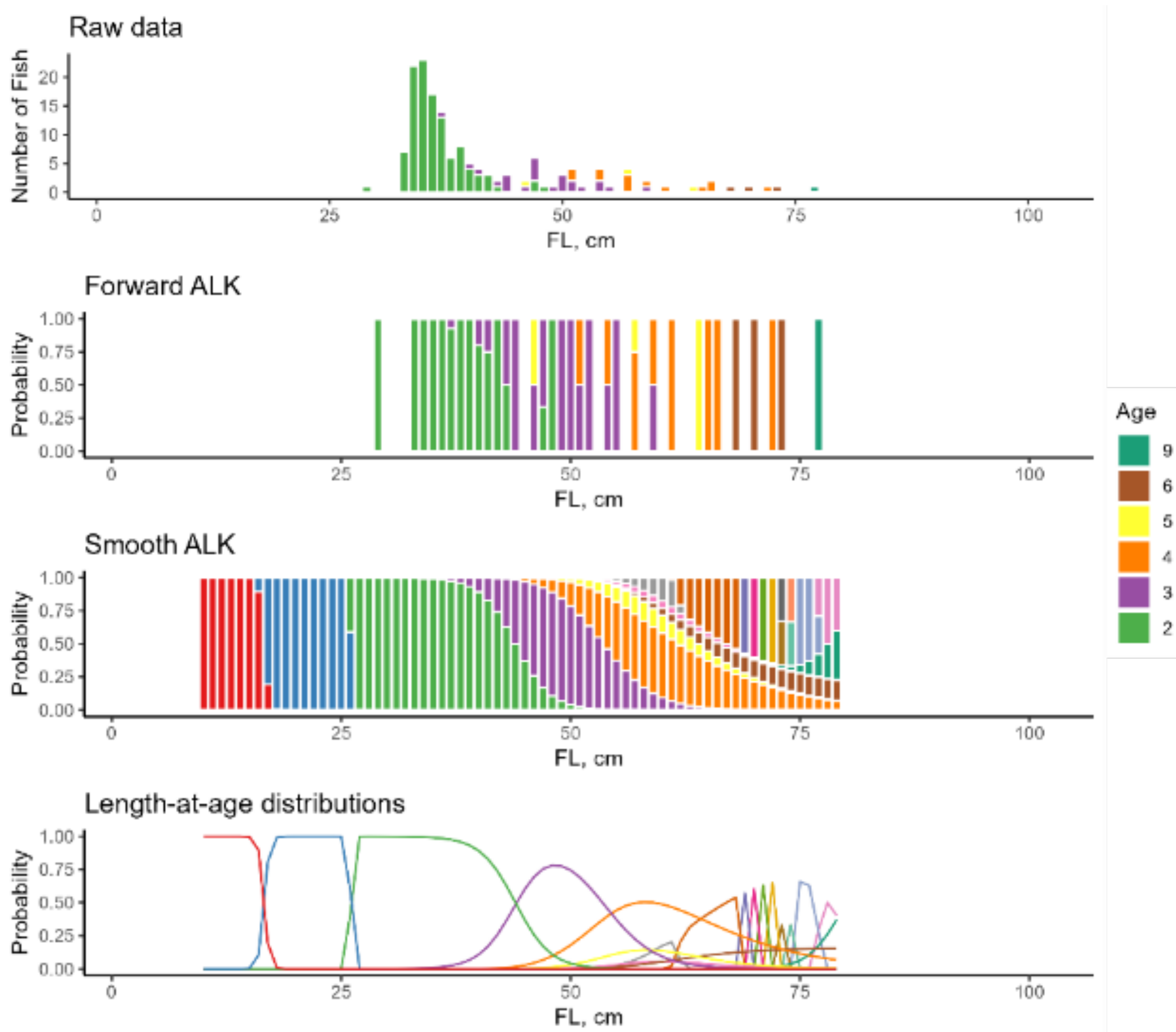

Figure 38. Age data and derived ALKs for 1997 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

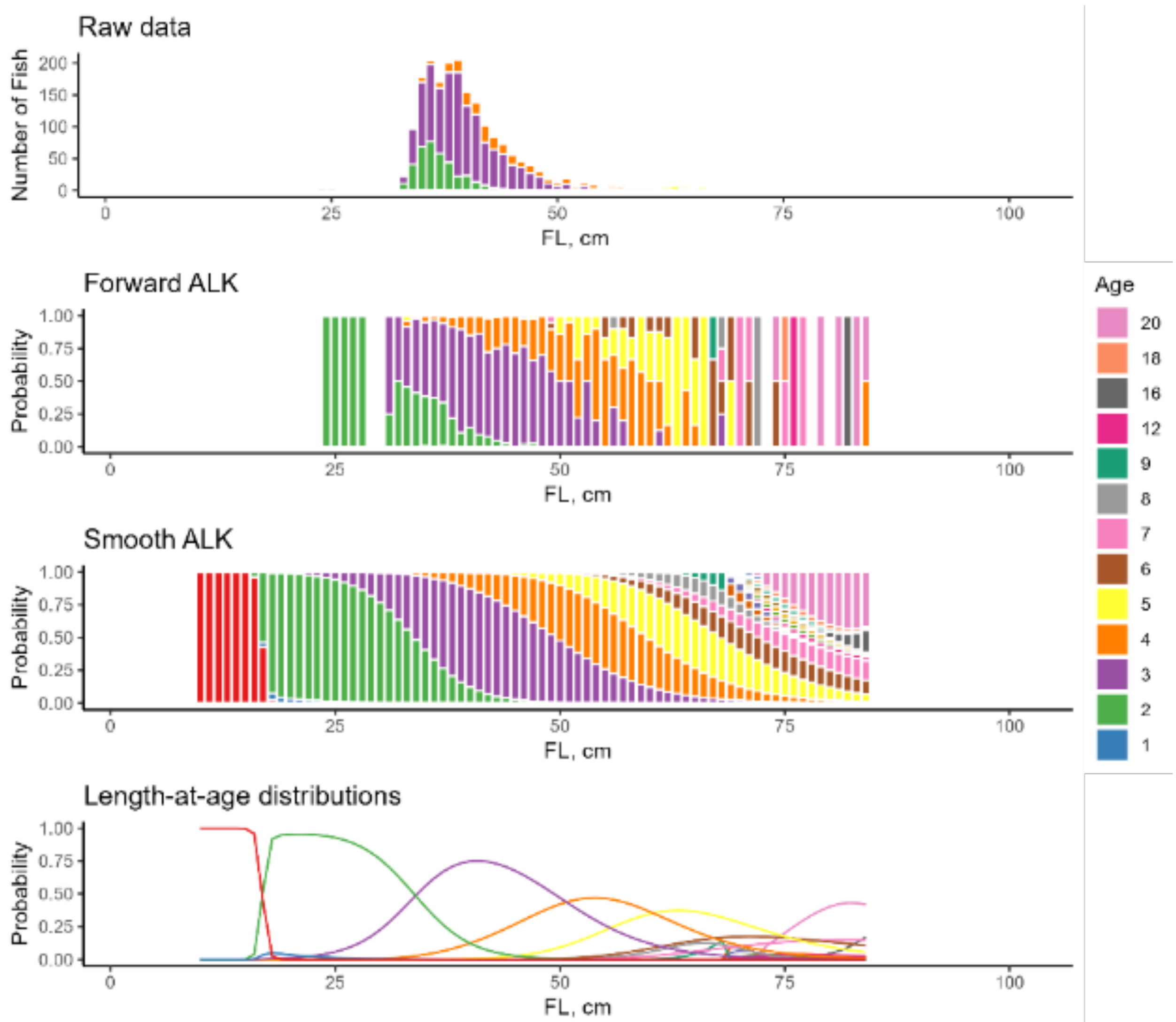

Figure 39. Age data and derived ALKs for 1998 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

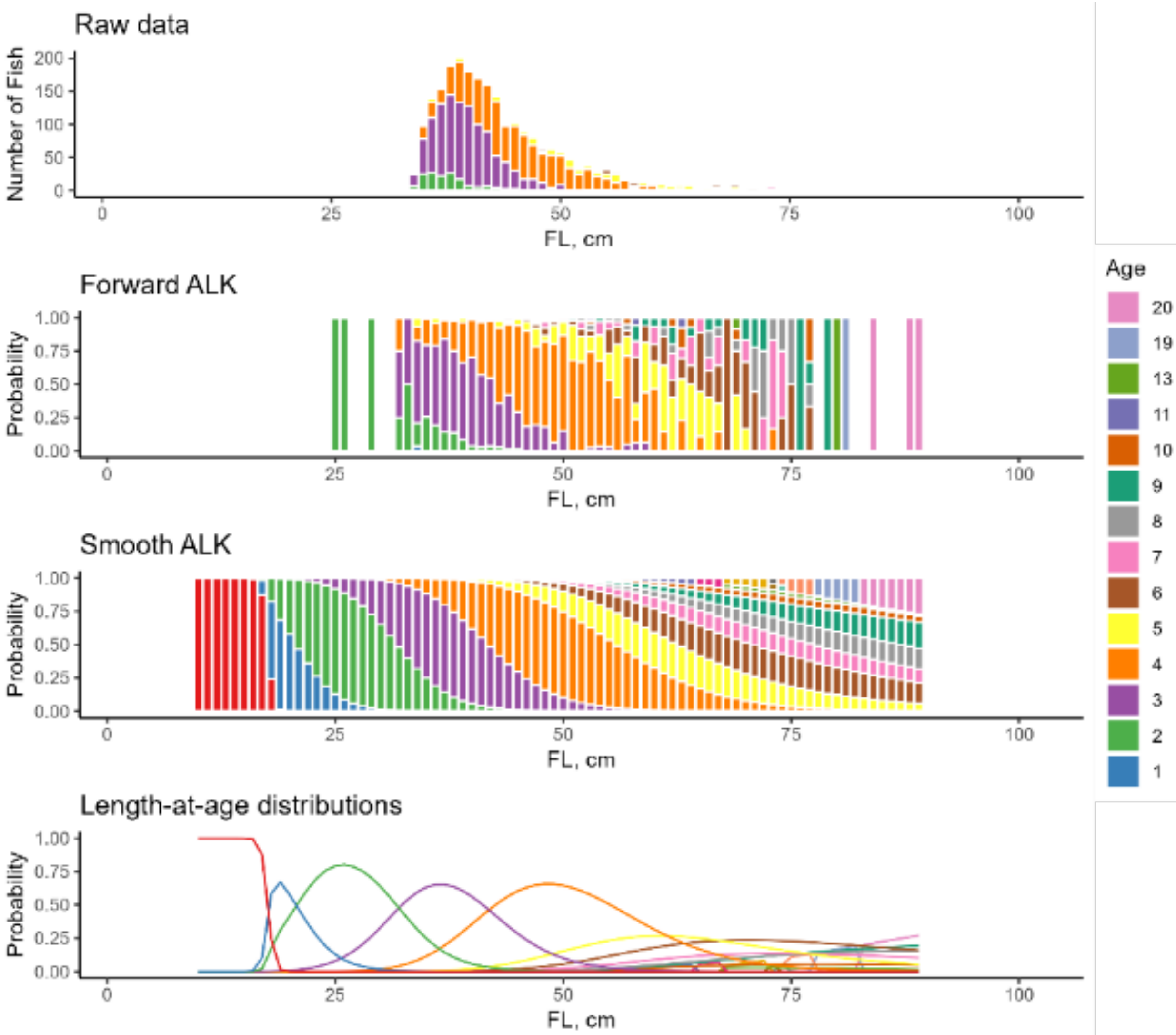

Figure 40. Age data and derived ALKs for 1999 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

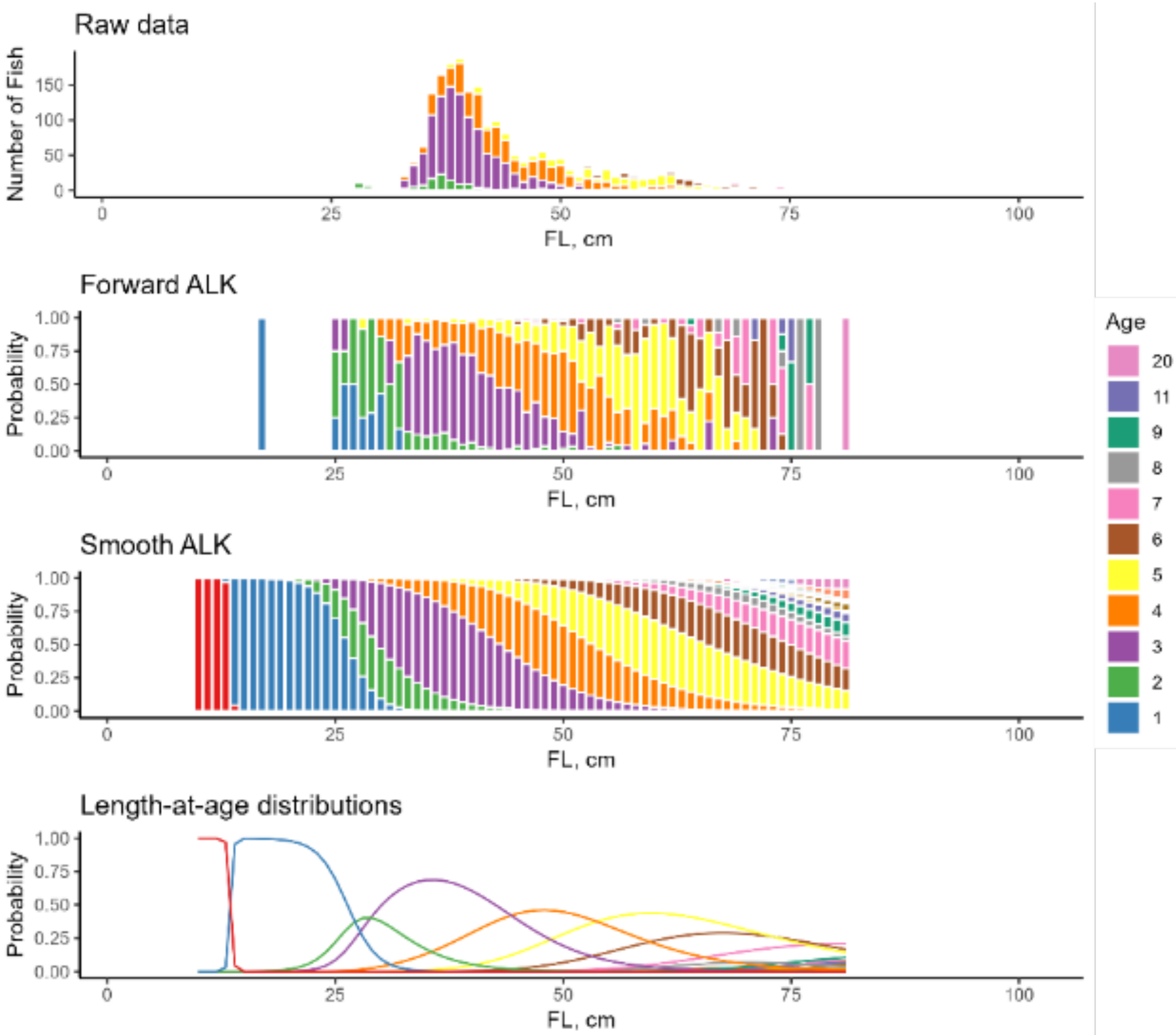

Figure 41. Age data and derived ALKs for 2000 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

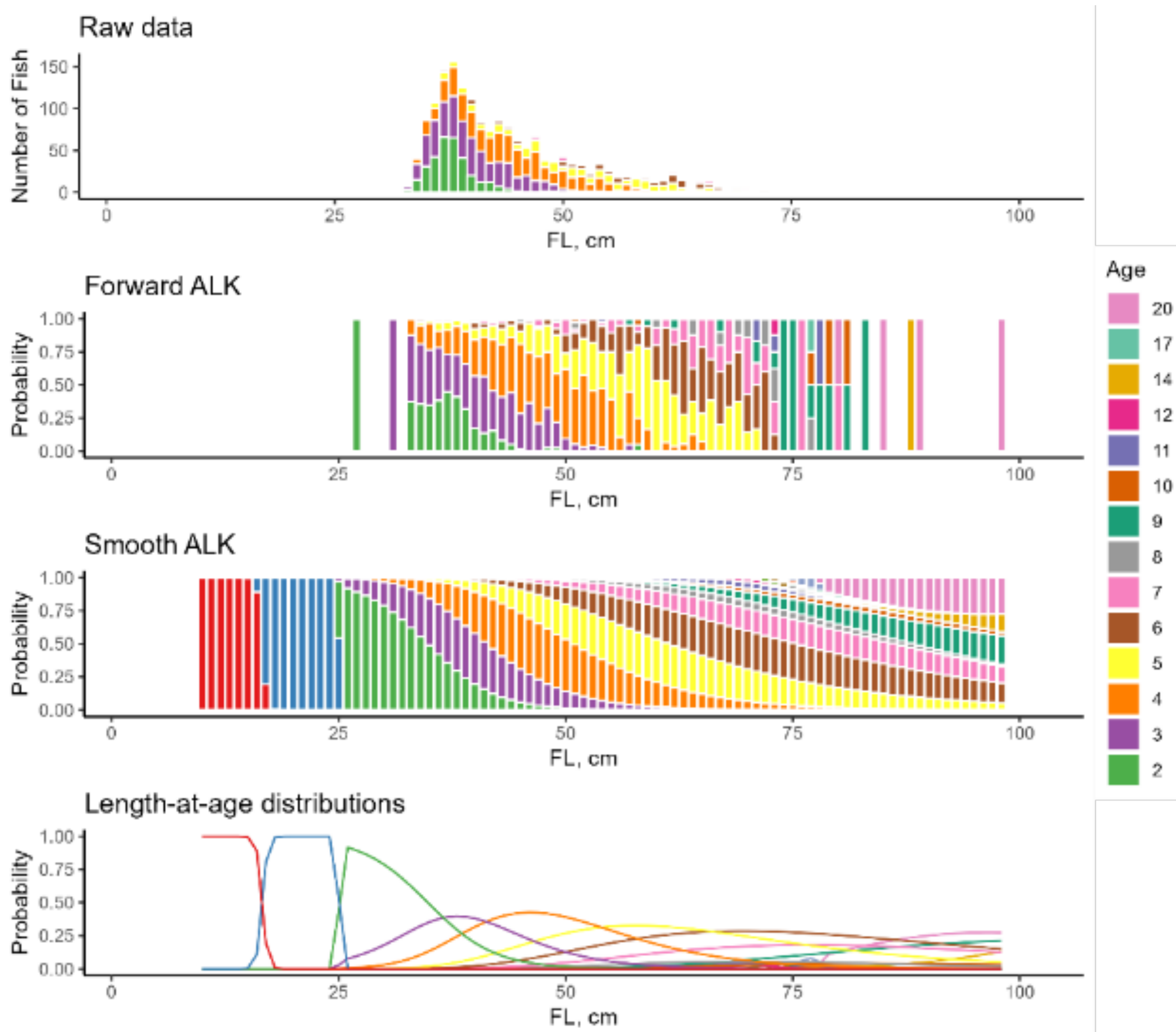

Figure 42. Age data and derived ALKs for 2001 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

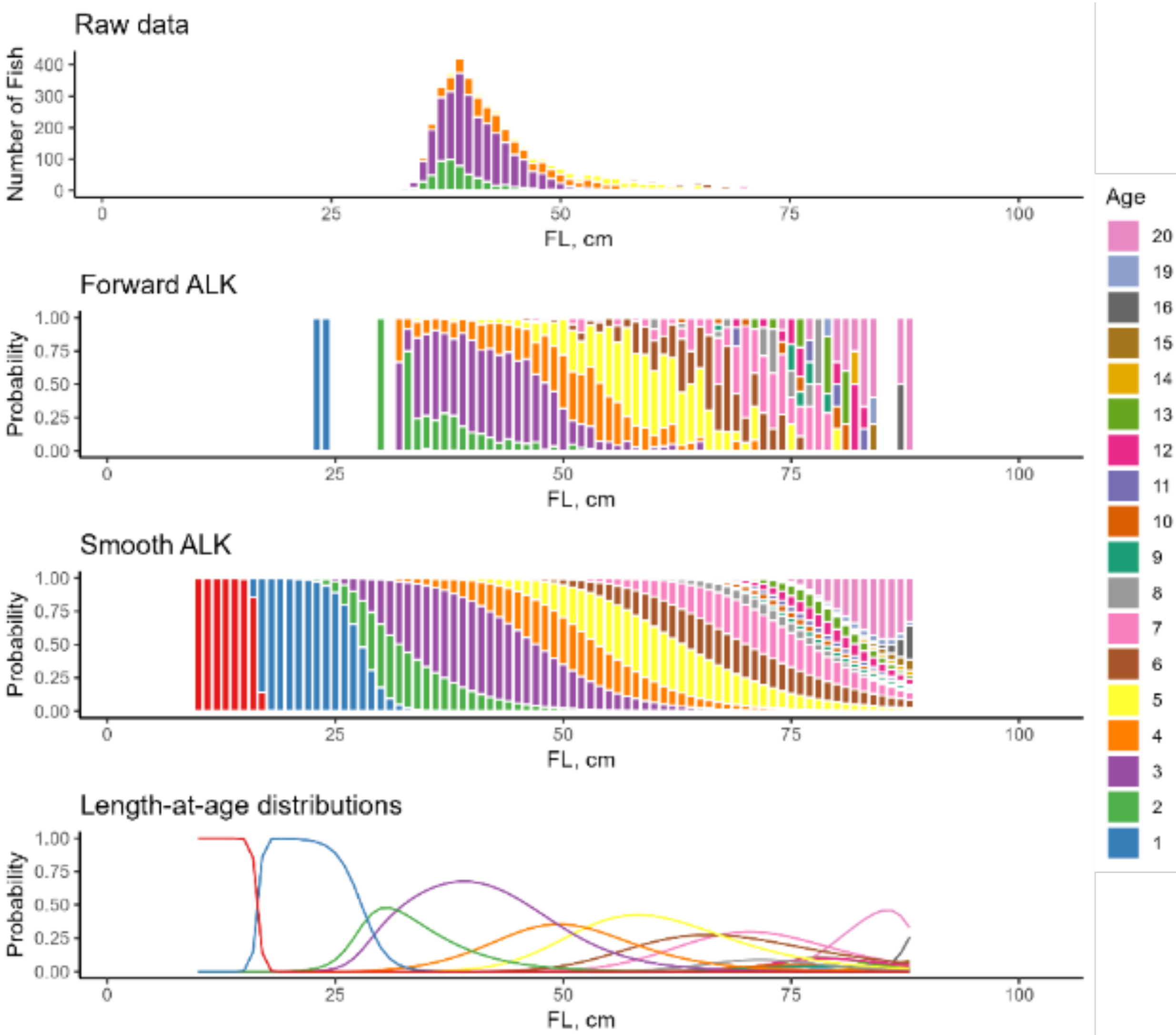

Figure 43. Age data and derived ALKs for 2002 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

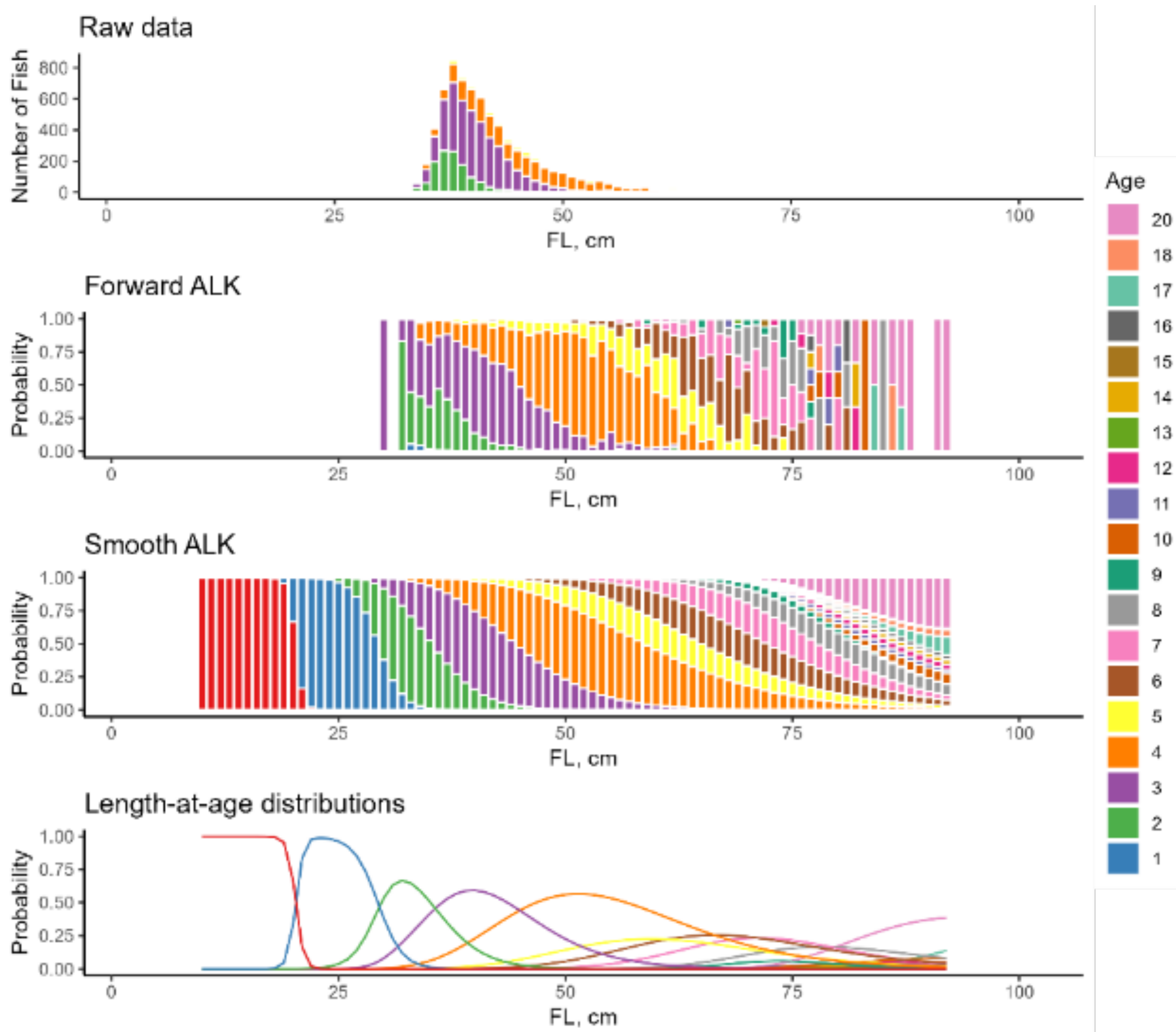

Figure 44. Age data and derived ALKs for 2003 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

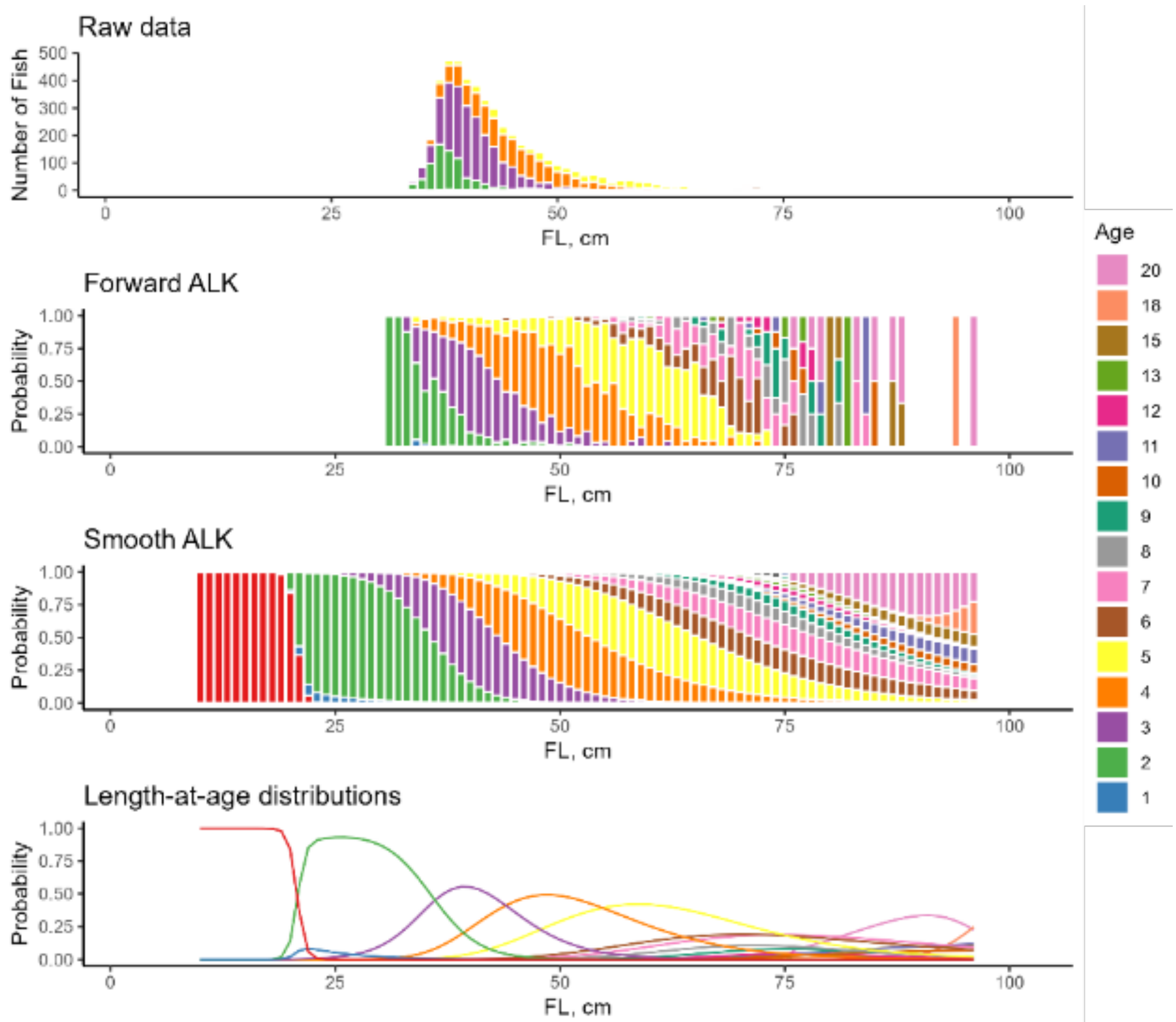

Figure 45. Age data and derived ALKs for 2004 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

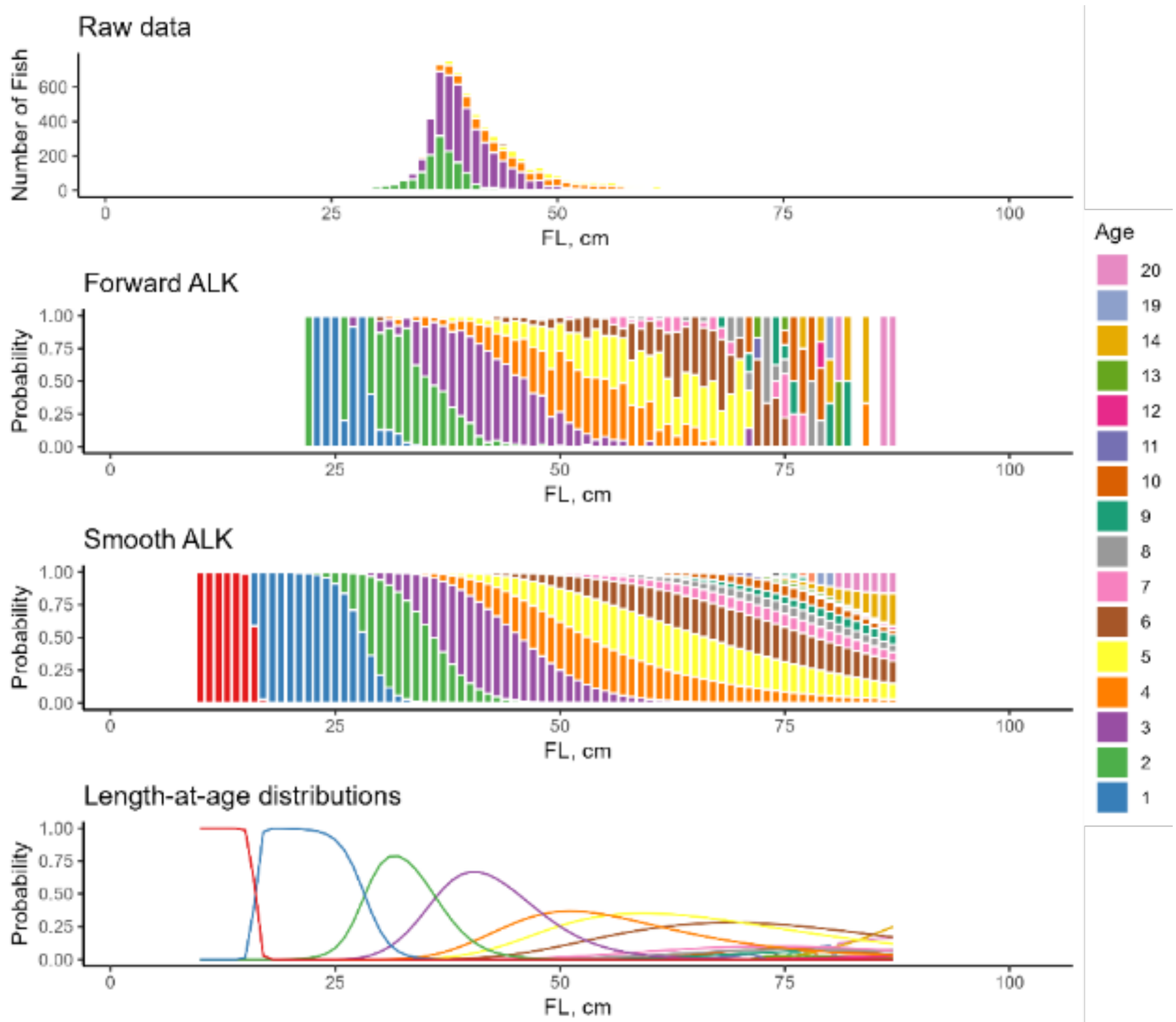

Figure 46. Age data and derived ALKs for 2005 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

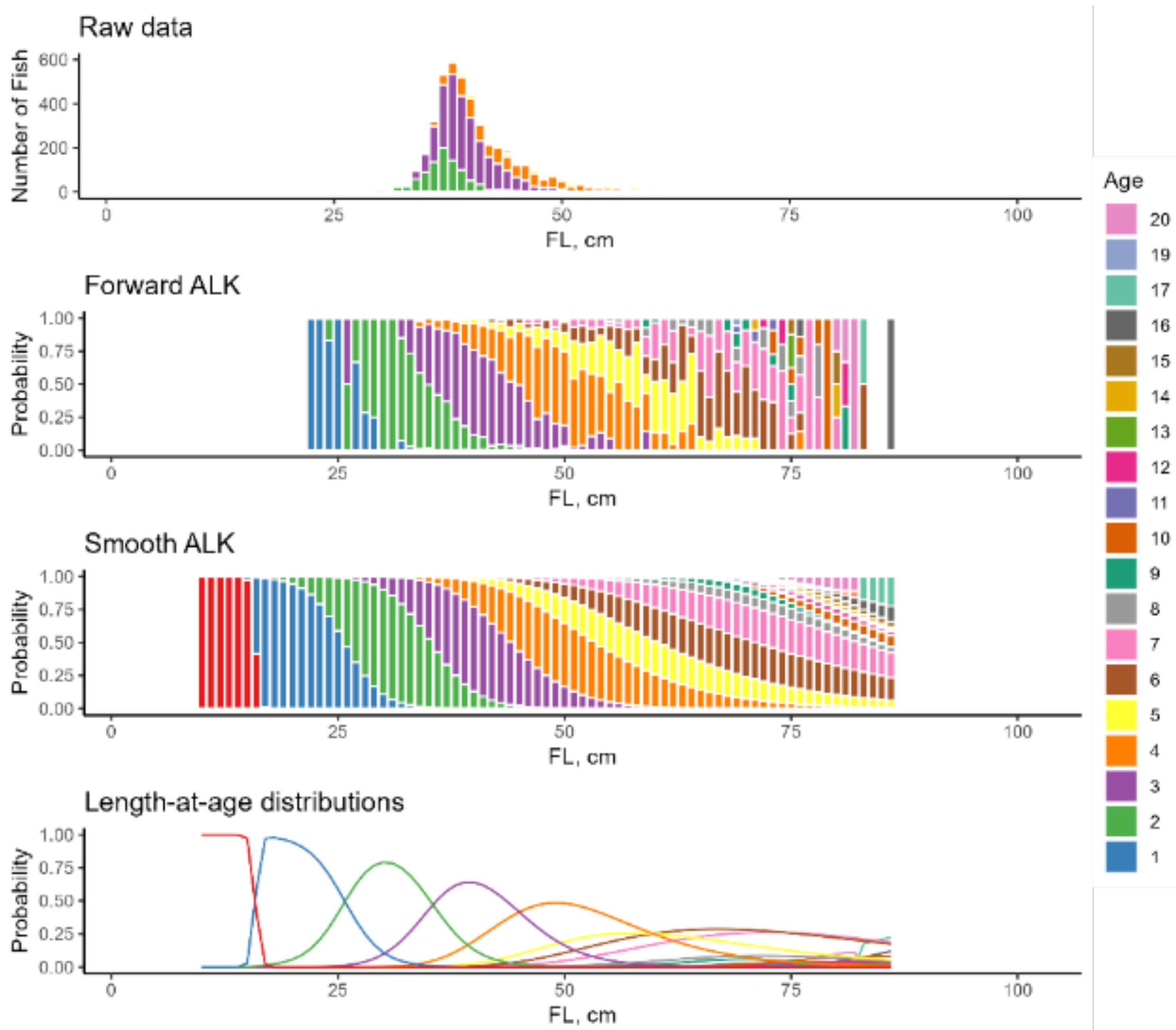

Figure 47. Age data and derived ALKs for 2006 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

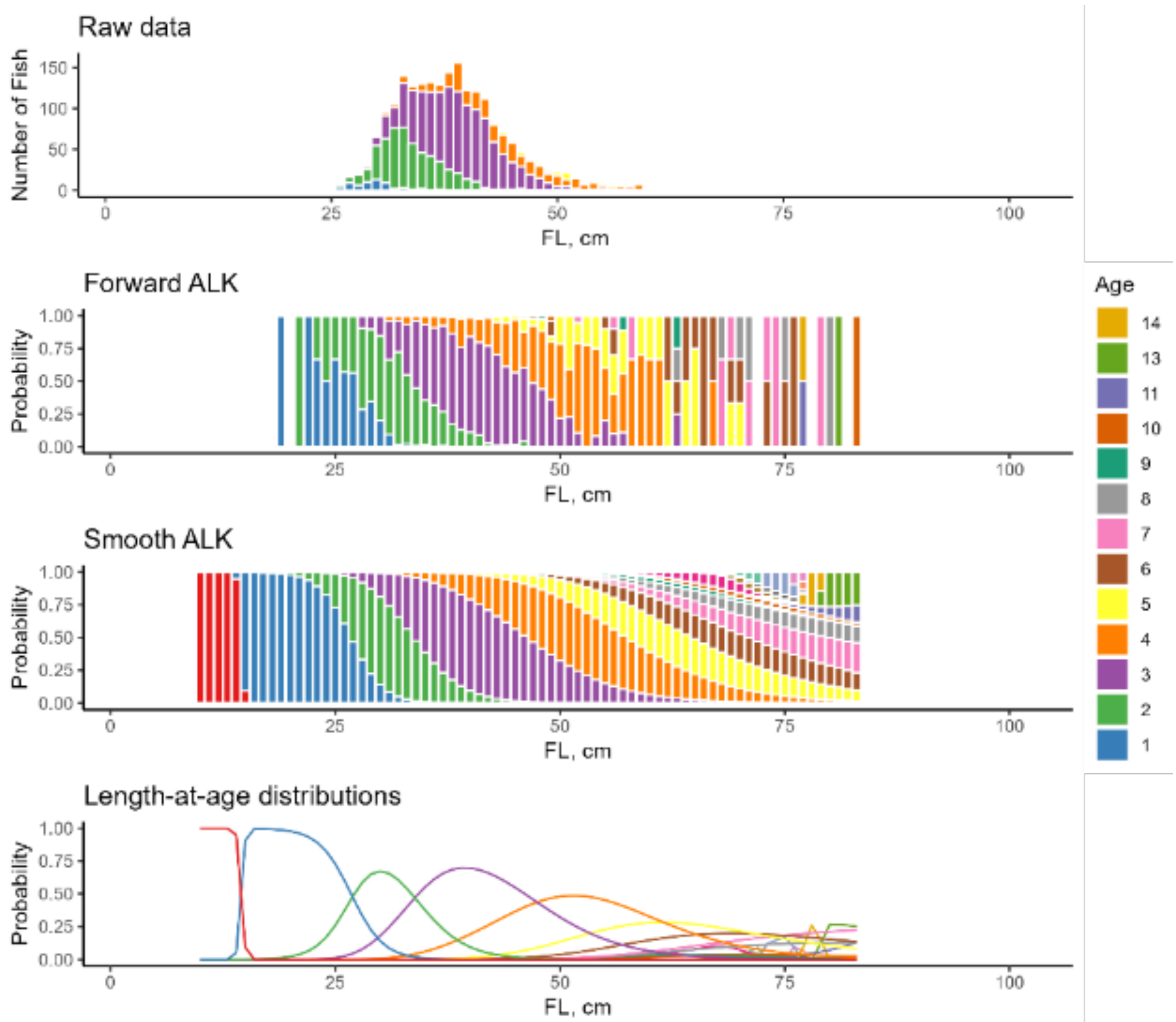

Figure 48. Age data and derived ALKs for 2007 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

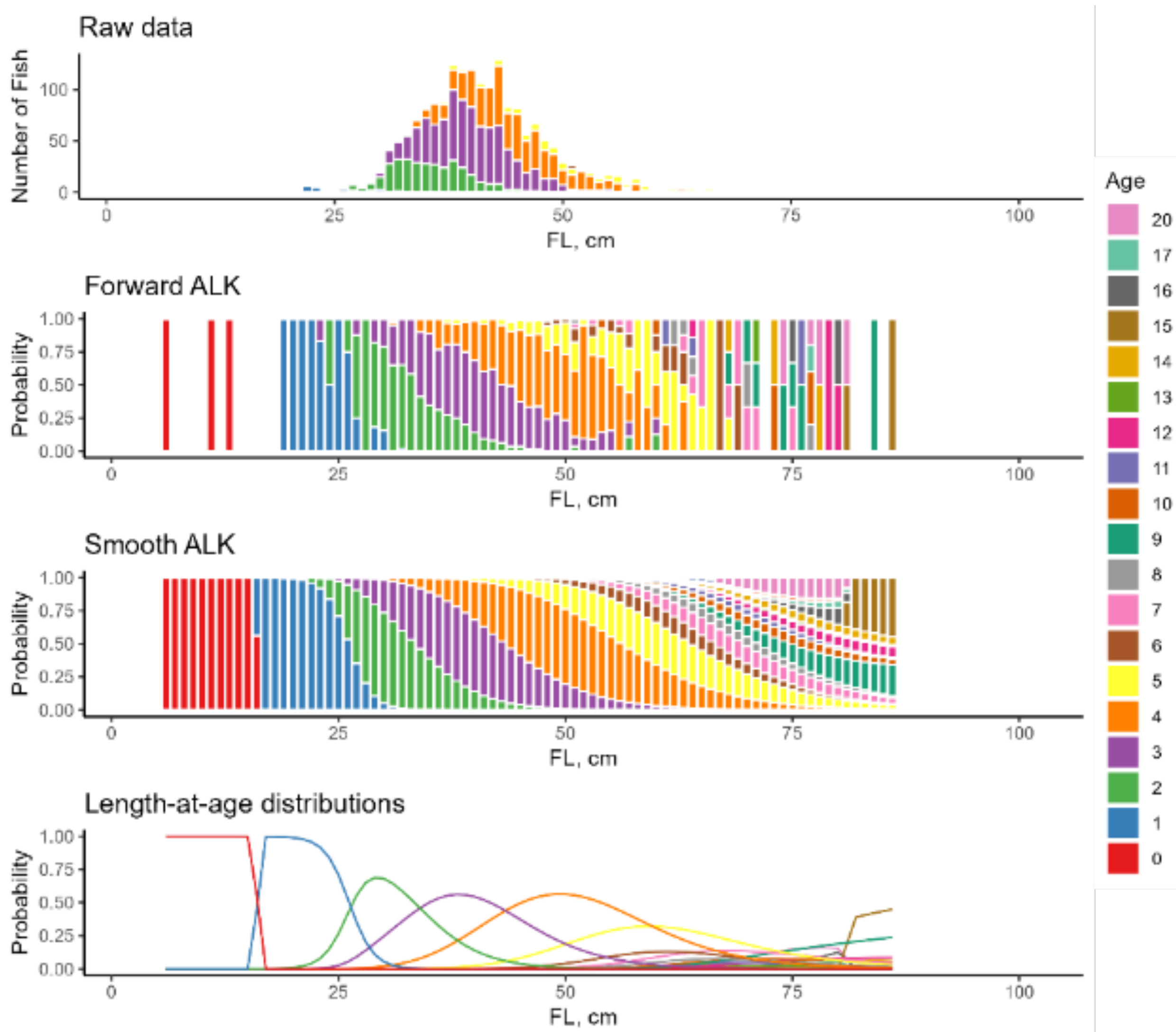

Figure 49. Age data and derived ALKs for 2008 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

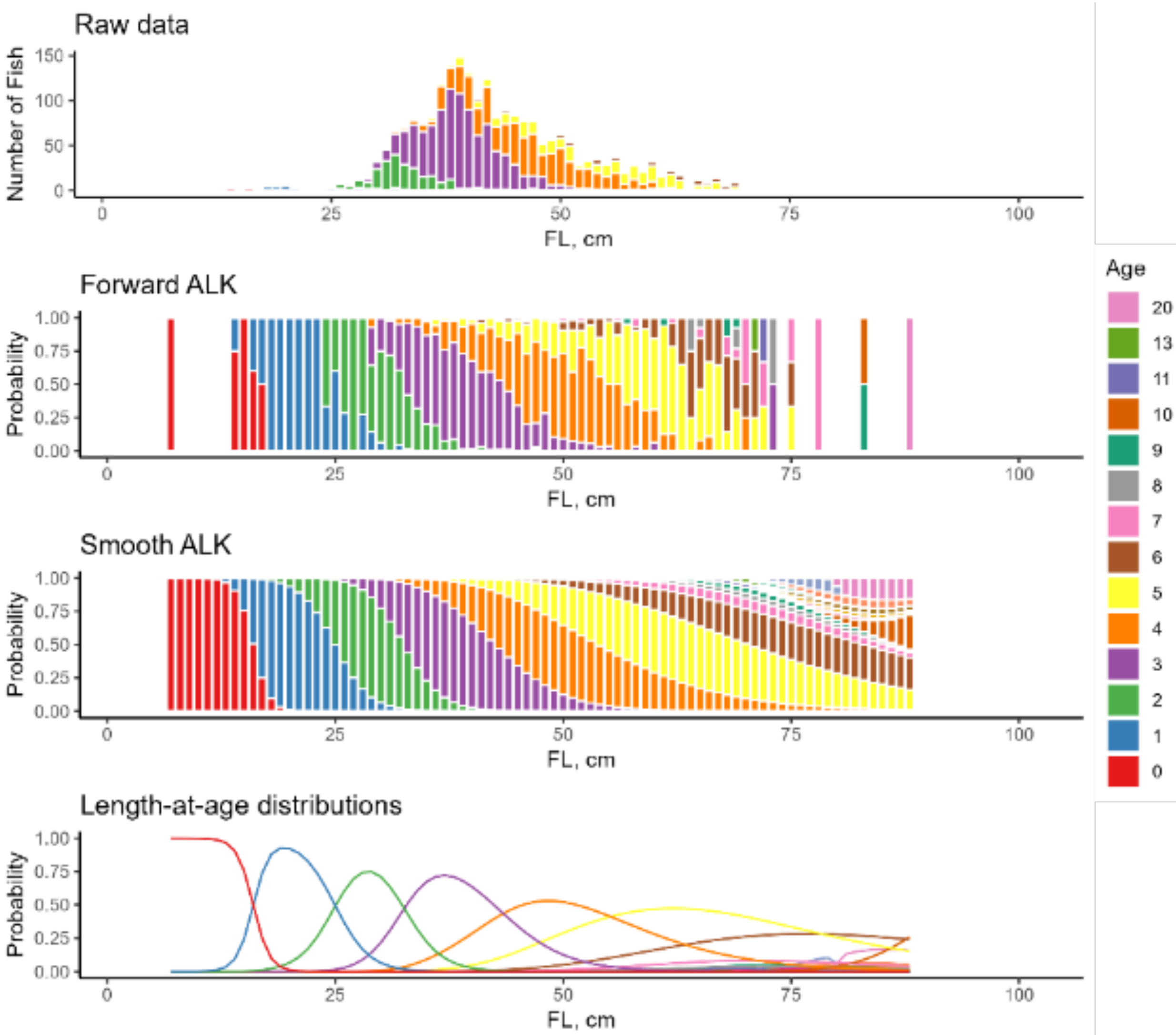

Figure 50. Age data and derived ALKs for 2009 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

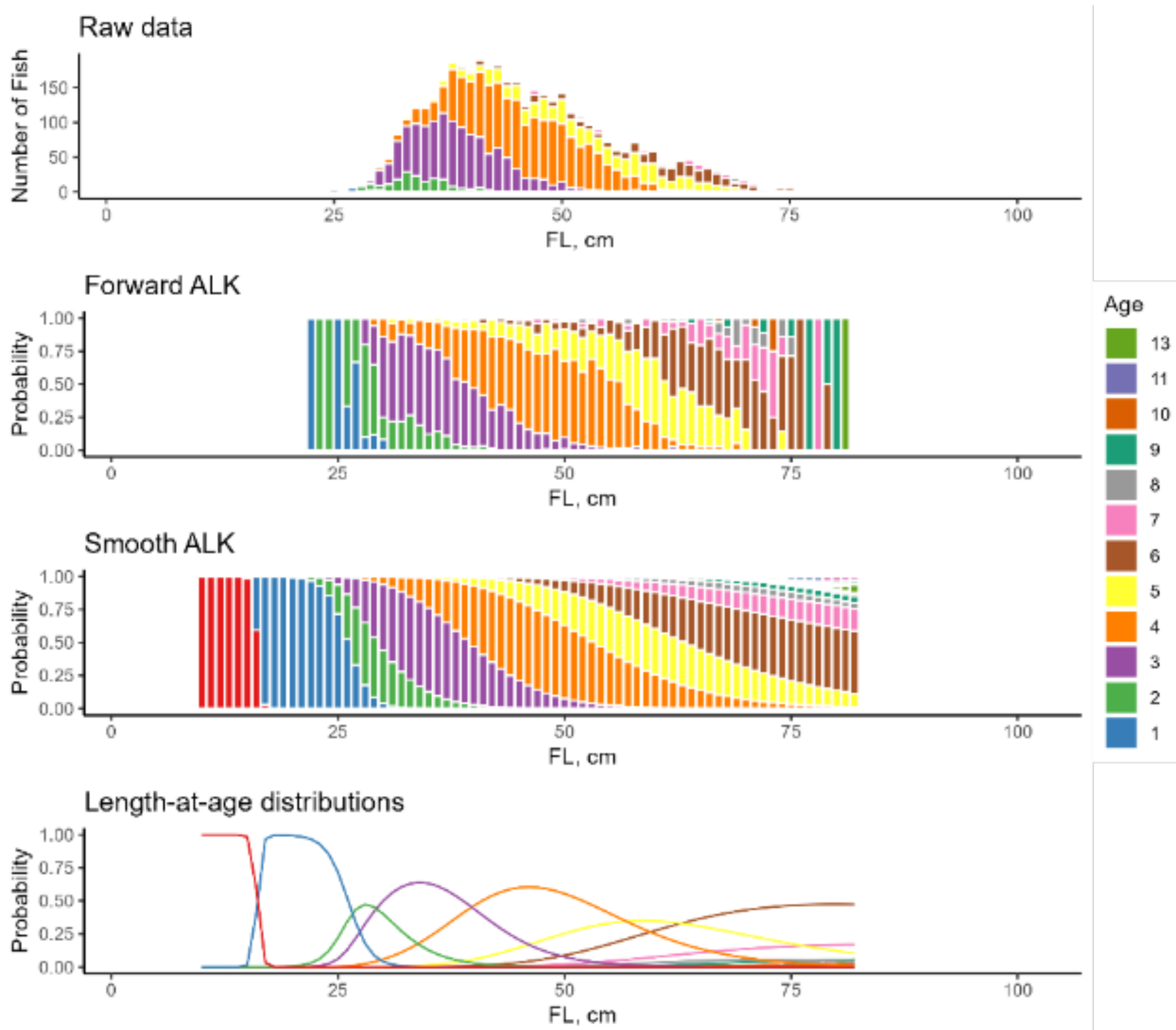

Figure 51. Age data and derived ALKs for 2010 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

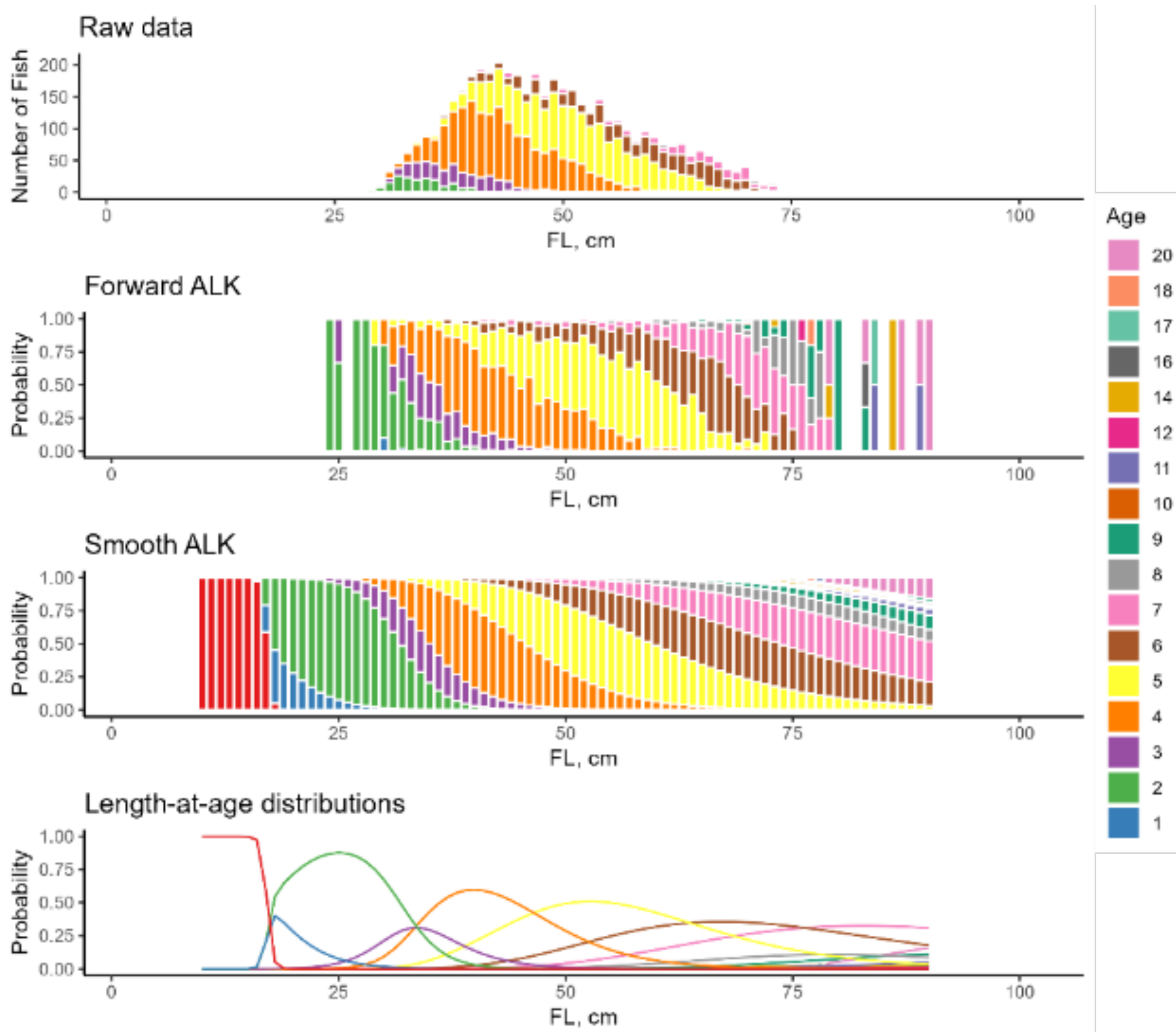

Figure 52. Age data and derived ALKs for 2011 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

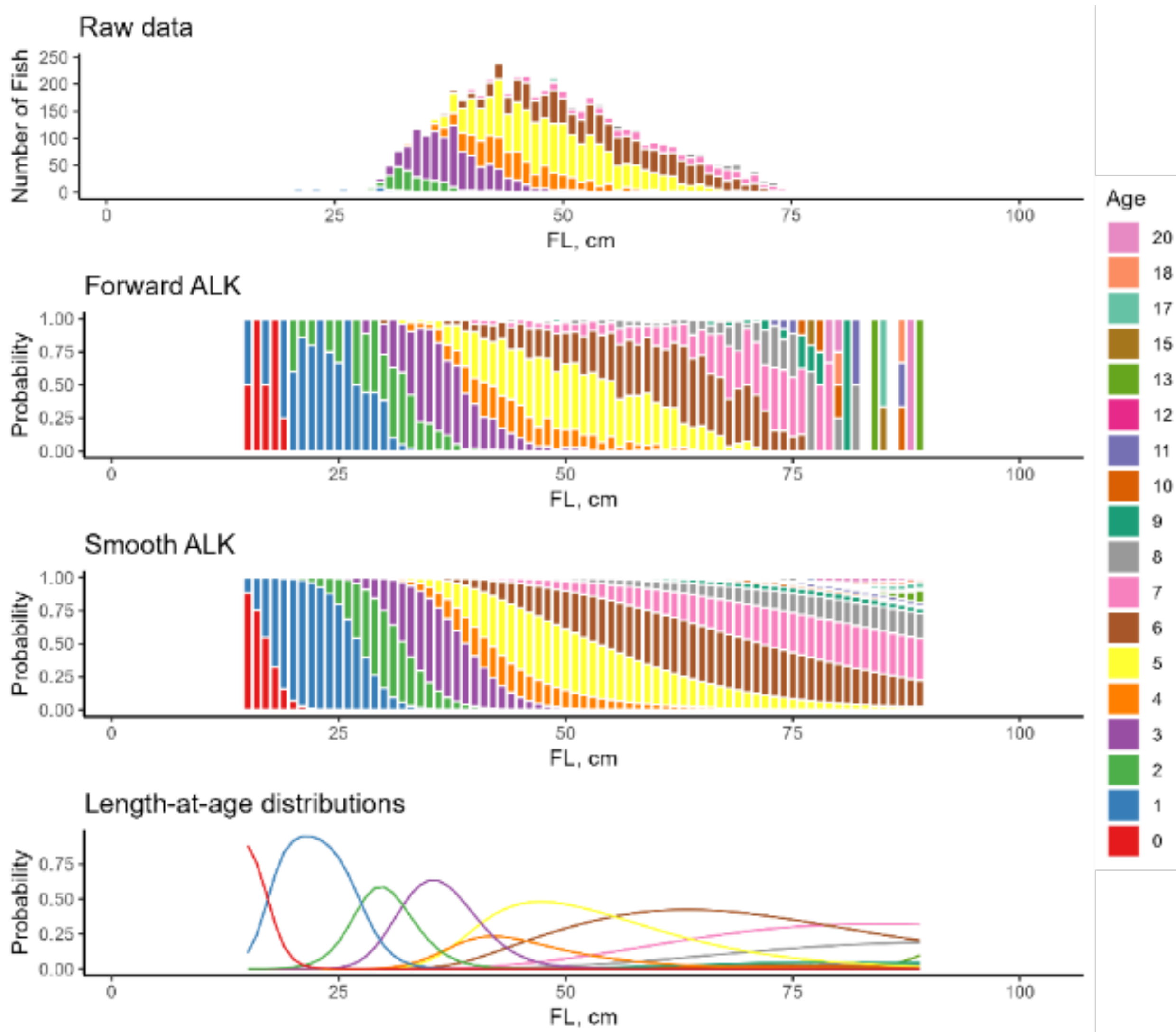

Figure 53. Age data and derived ALKs for 2012 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

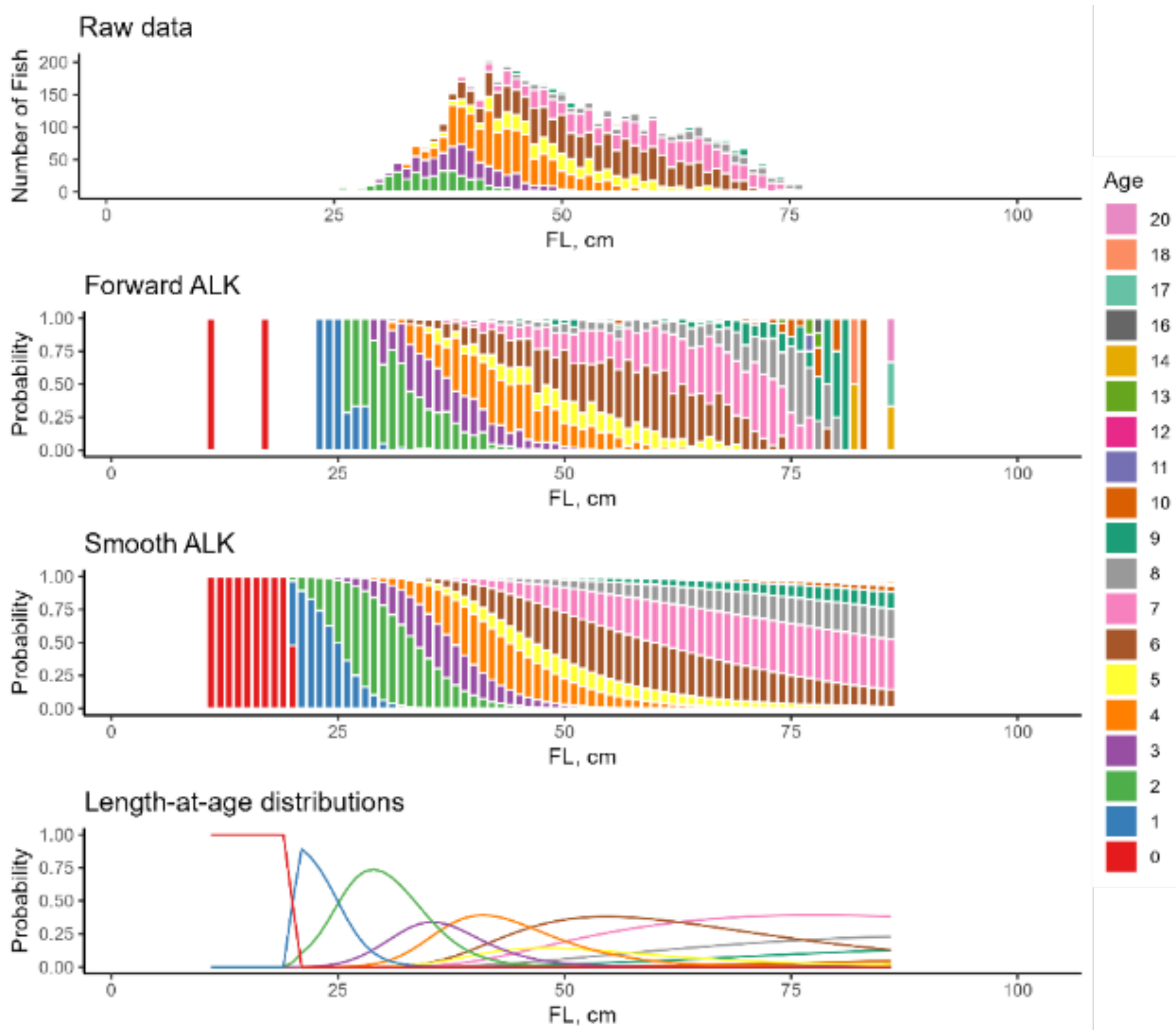

Figure 54. Age data and derived ALKs for 2013 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

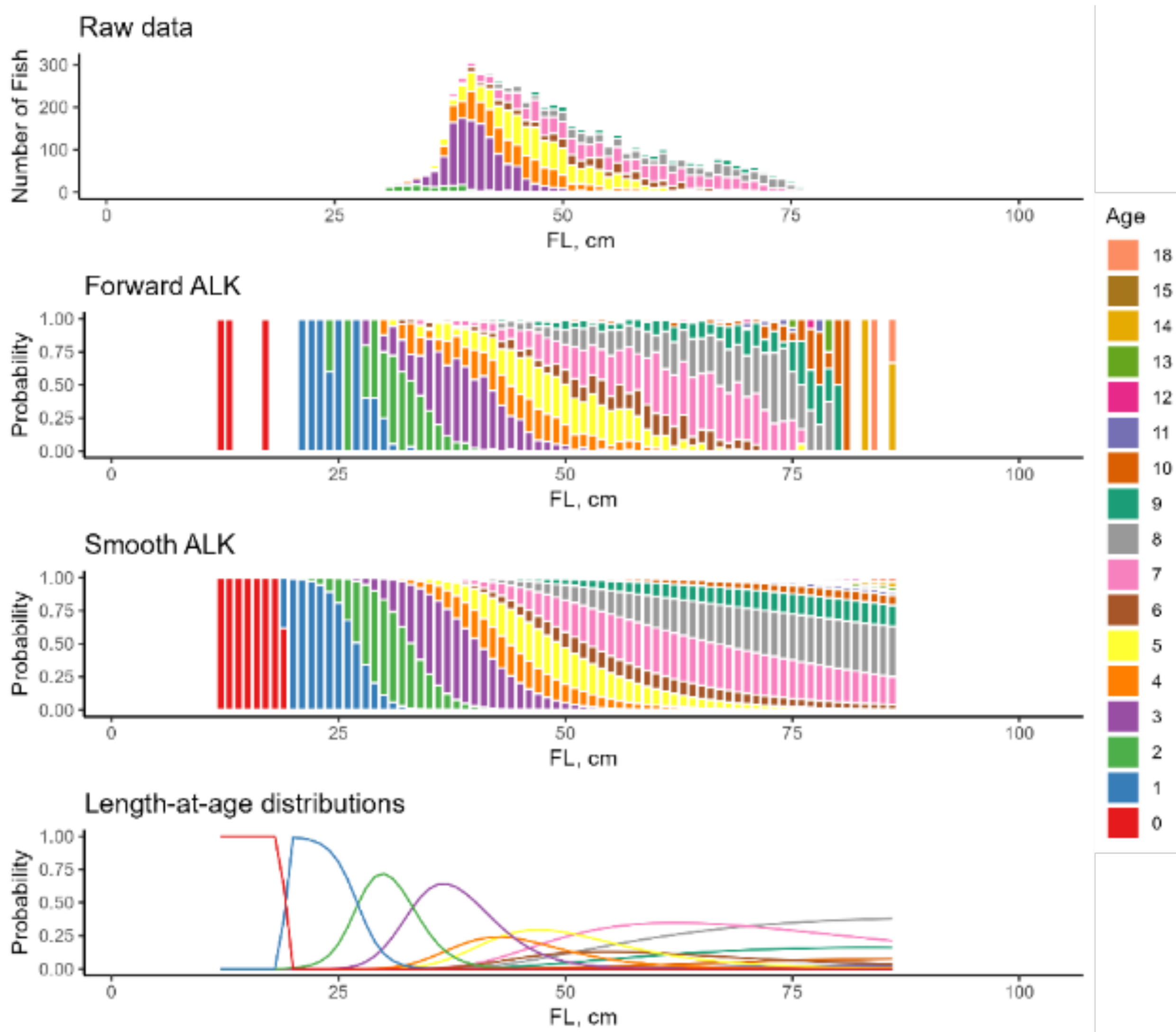

Figure 55. Age data and derived ALKs for 2014 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

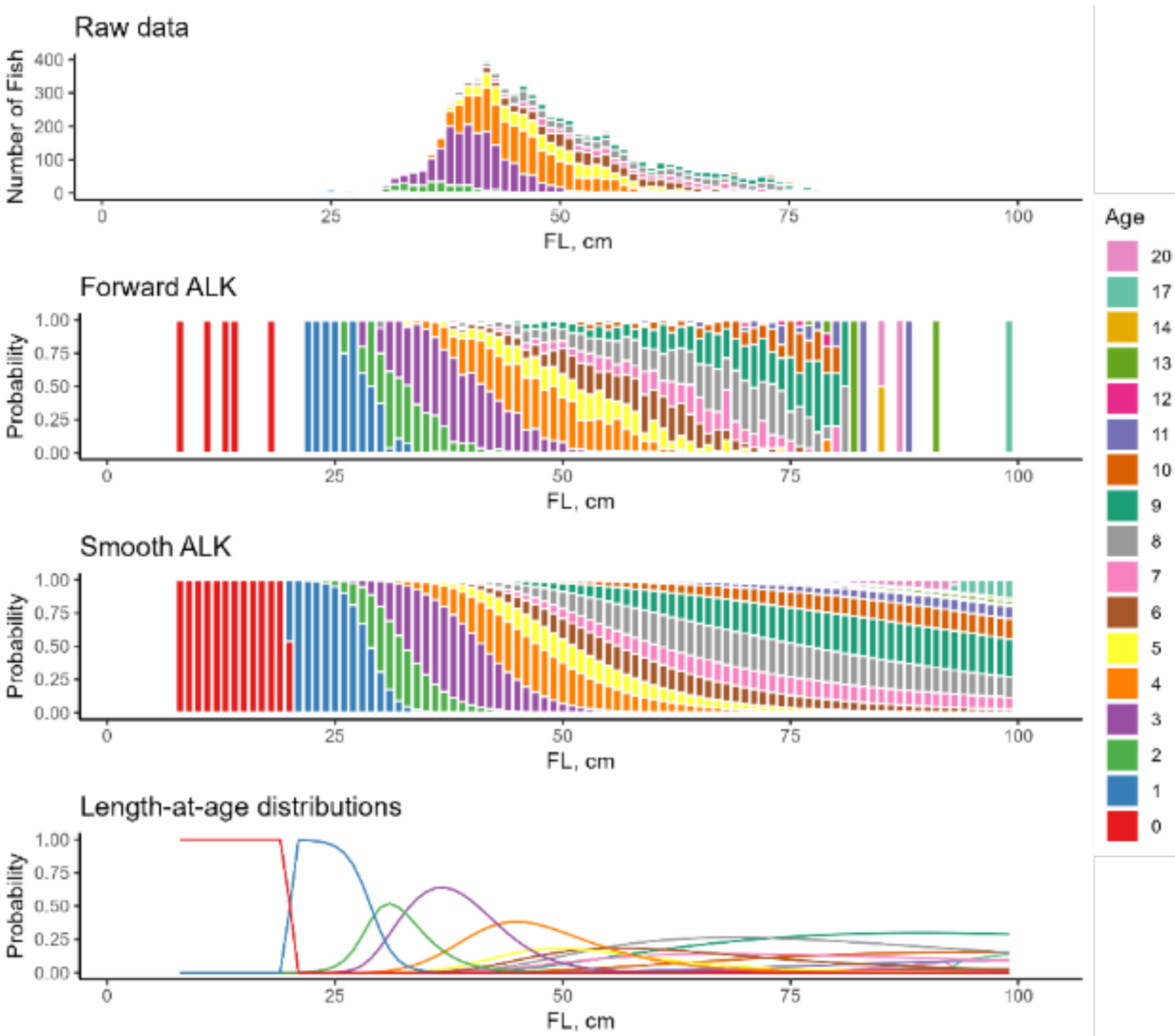

Figure 56. Age data and derived ALKs for 2015 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

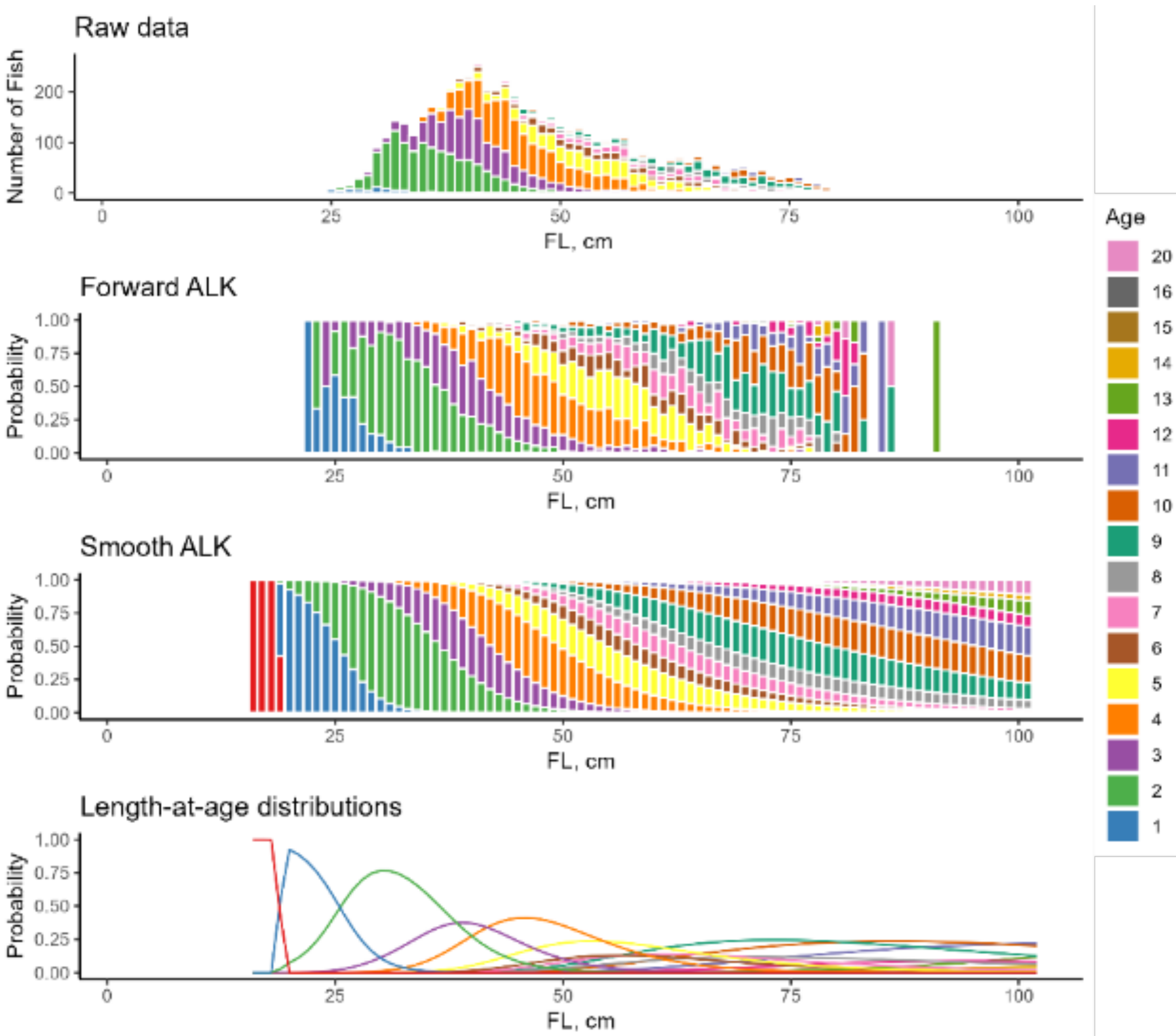

Figure 57. Age data and derived ALKs for 2016 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

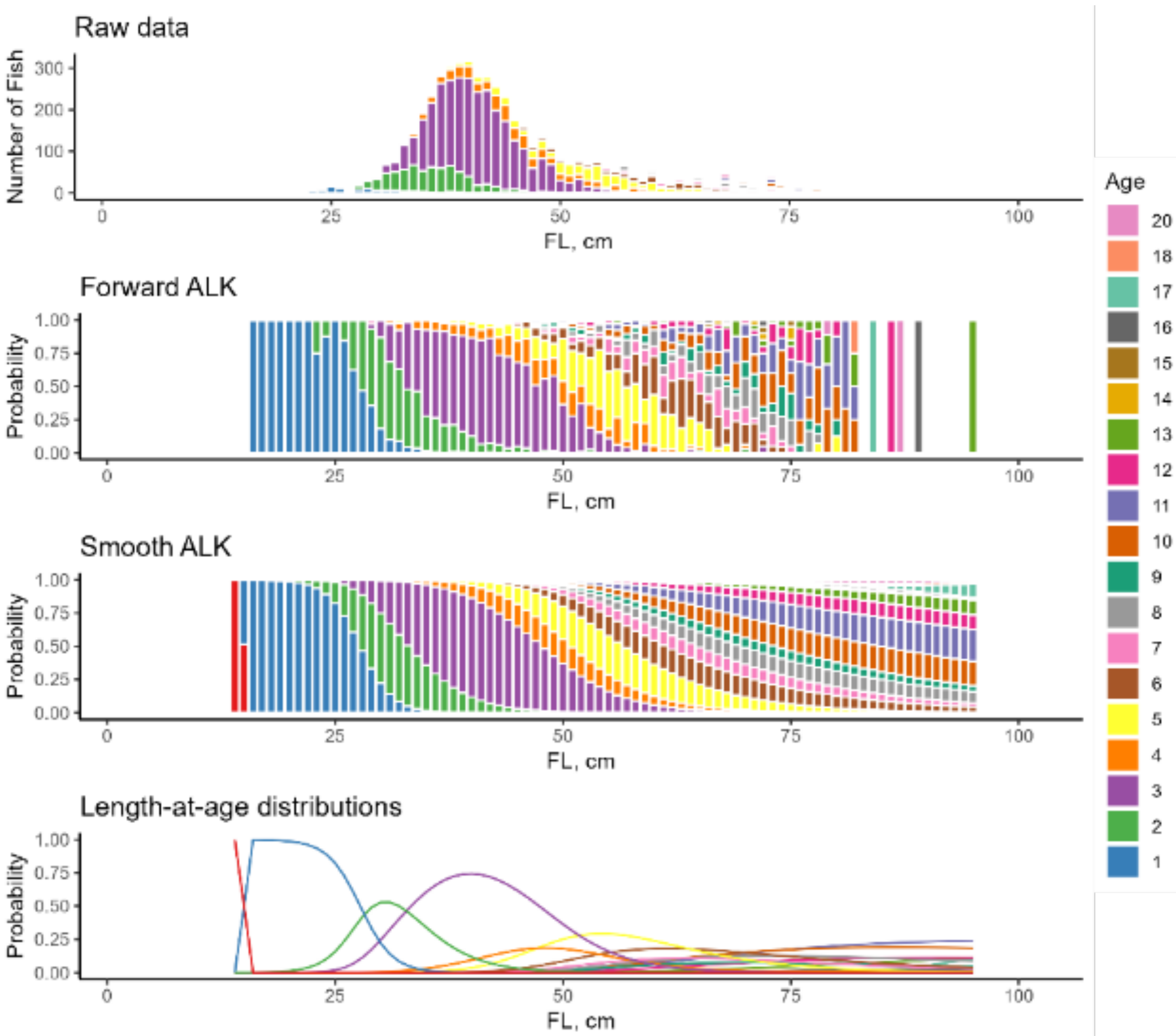

Figure 58. Age data and derived ALKs for 2017 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

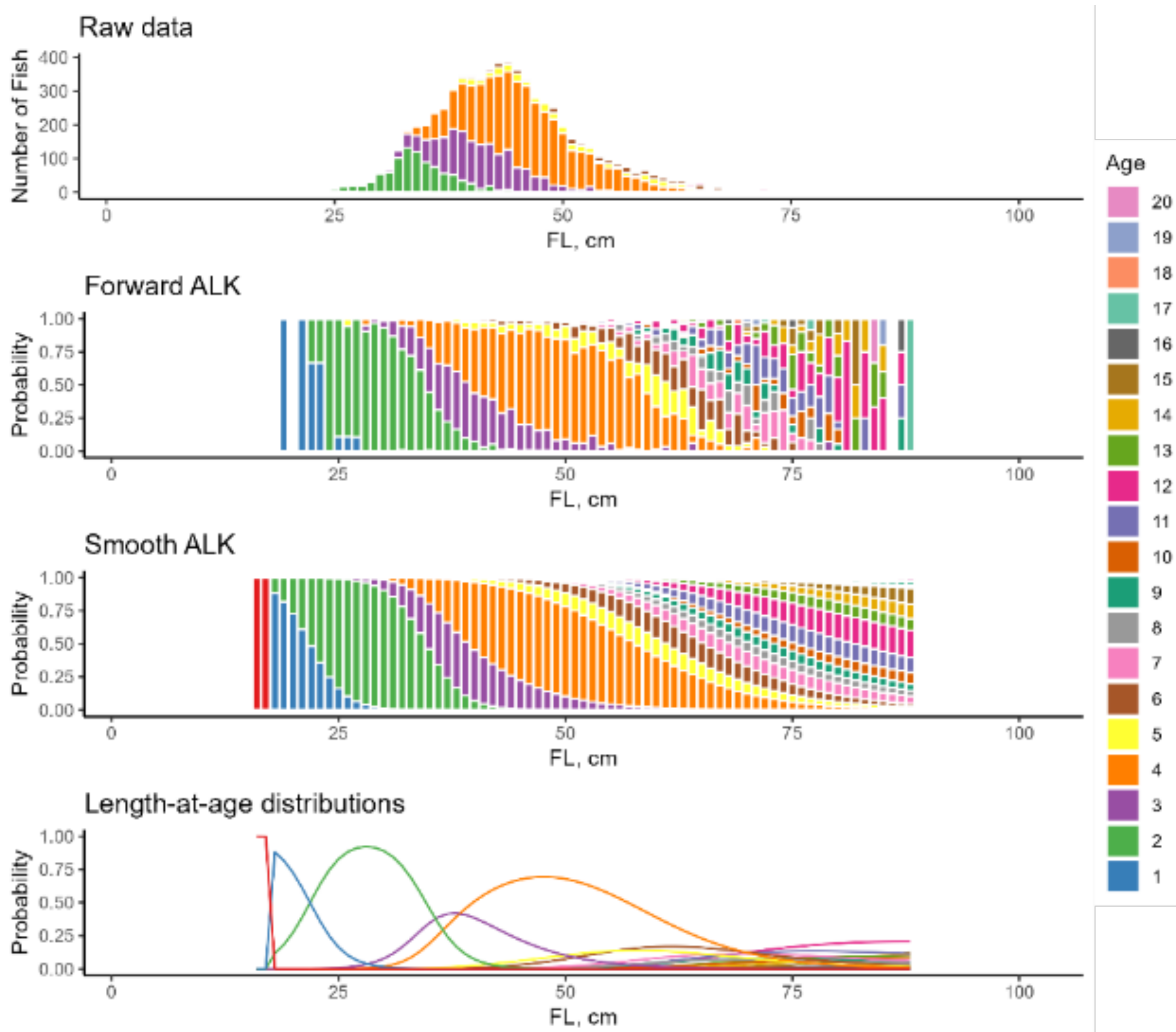

Figure 59. Age data and derived ALKs for 2018 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

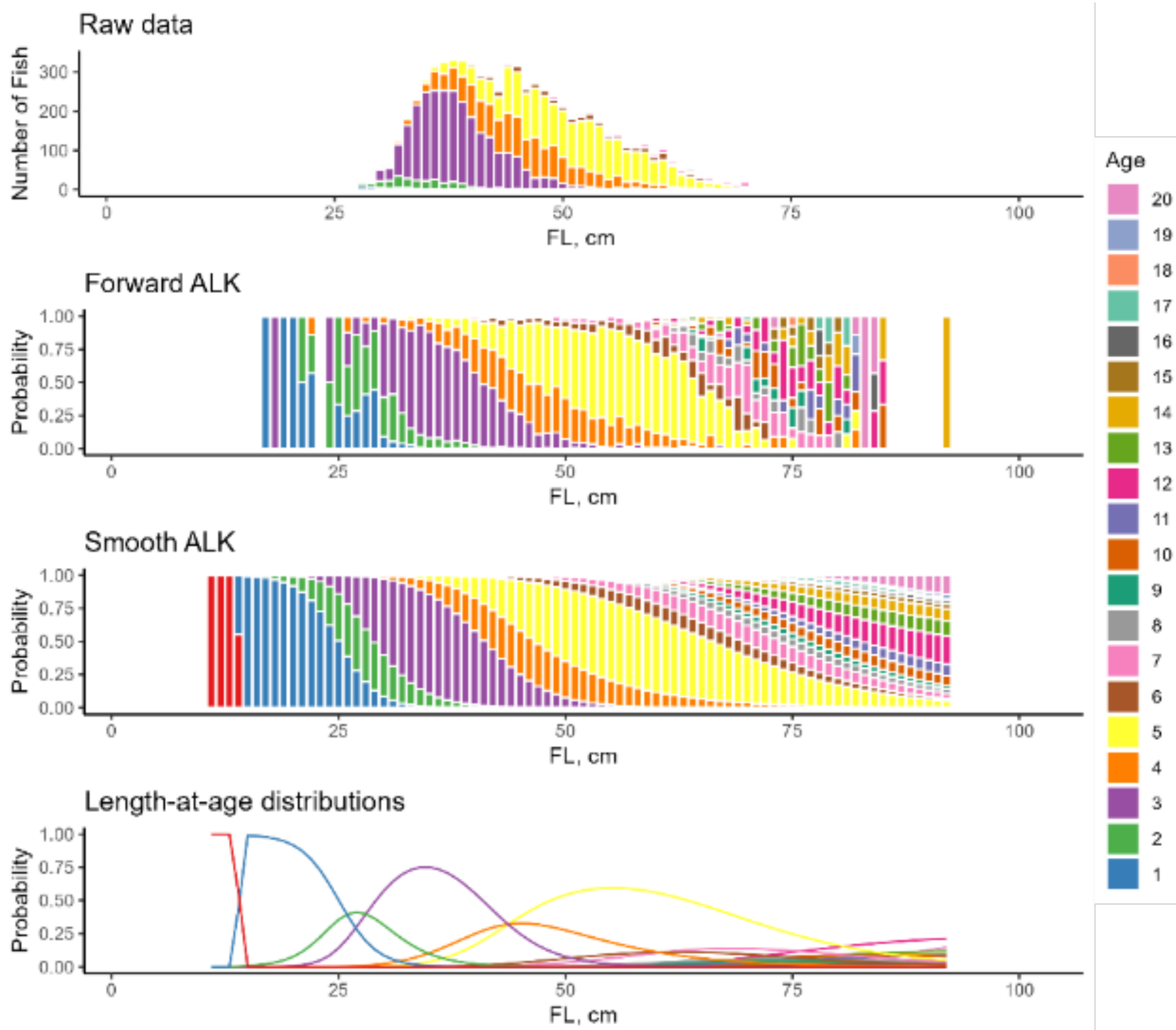

Figure 60. Age data and derived ALKs for 2019 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

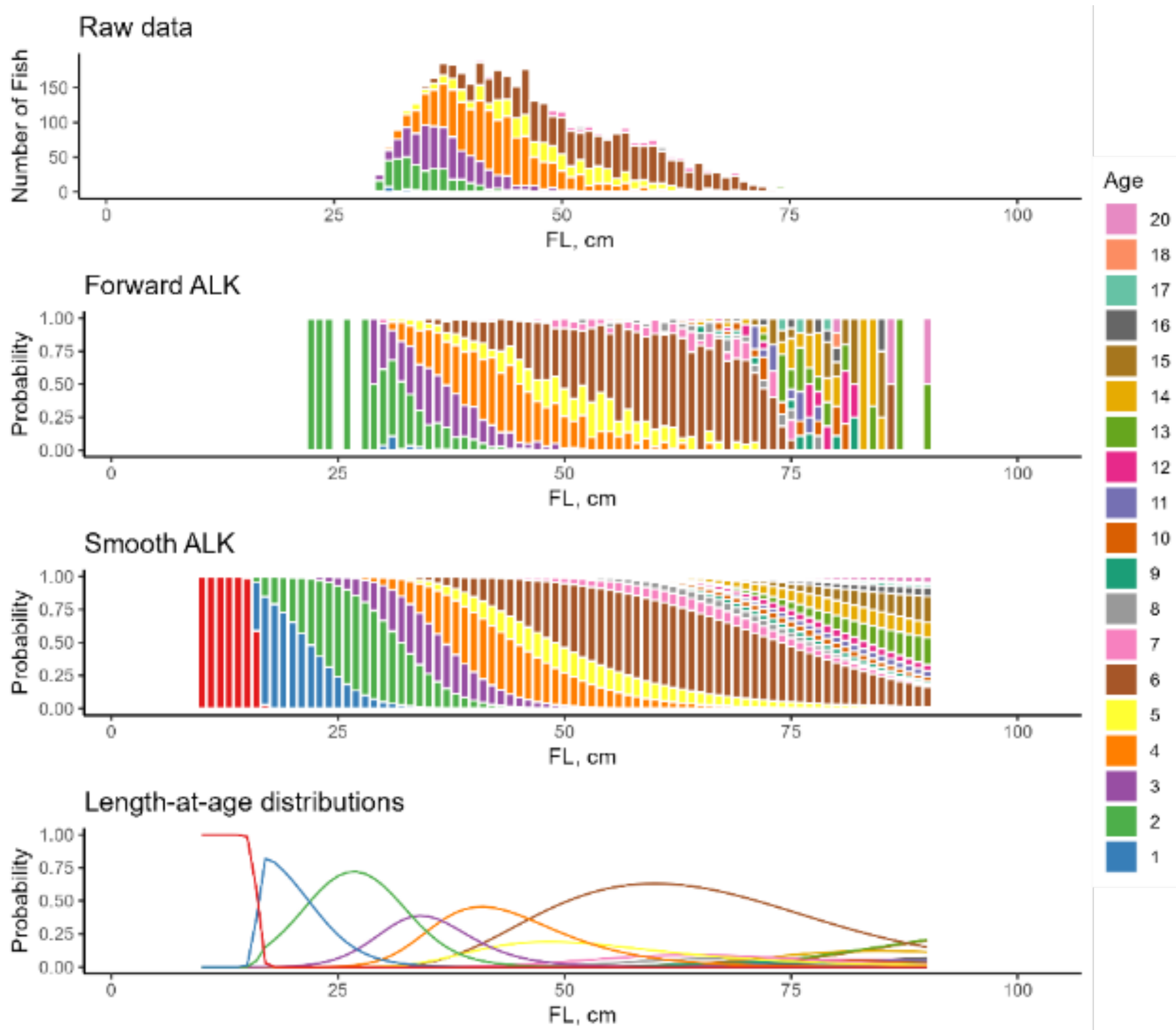

Figure 61. Age data and derived ALKs for 2020 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

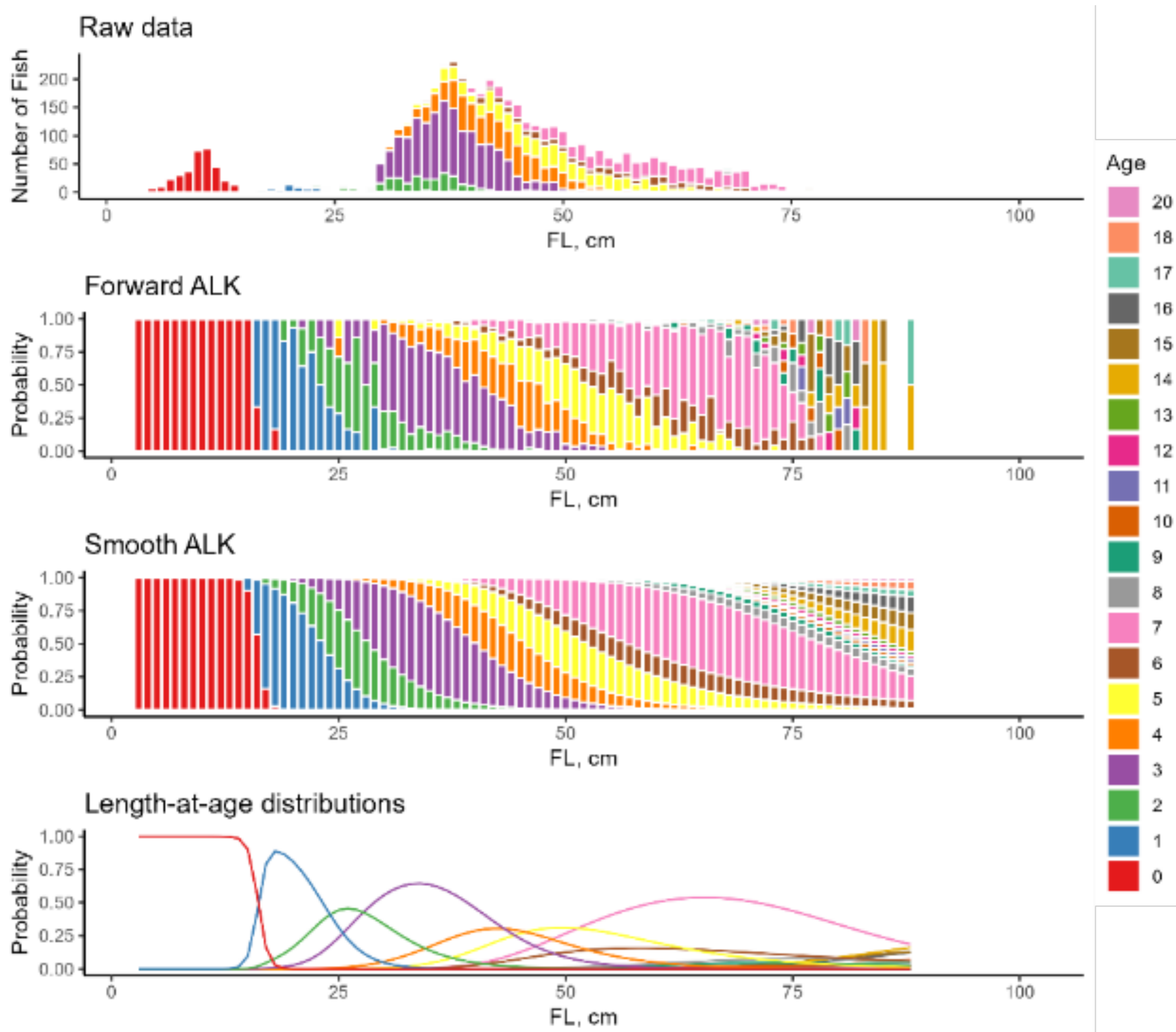

Figure 62. Age data and derived ALKs for 2021 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

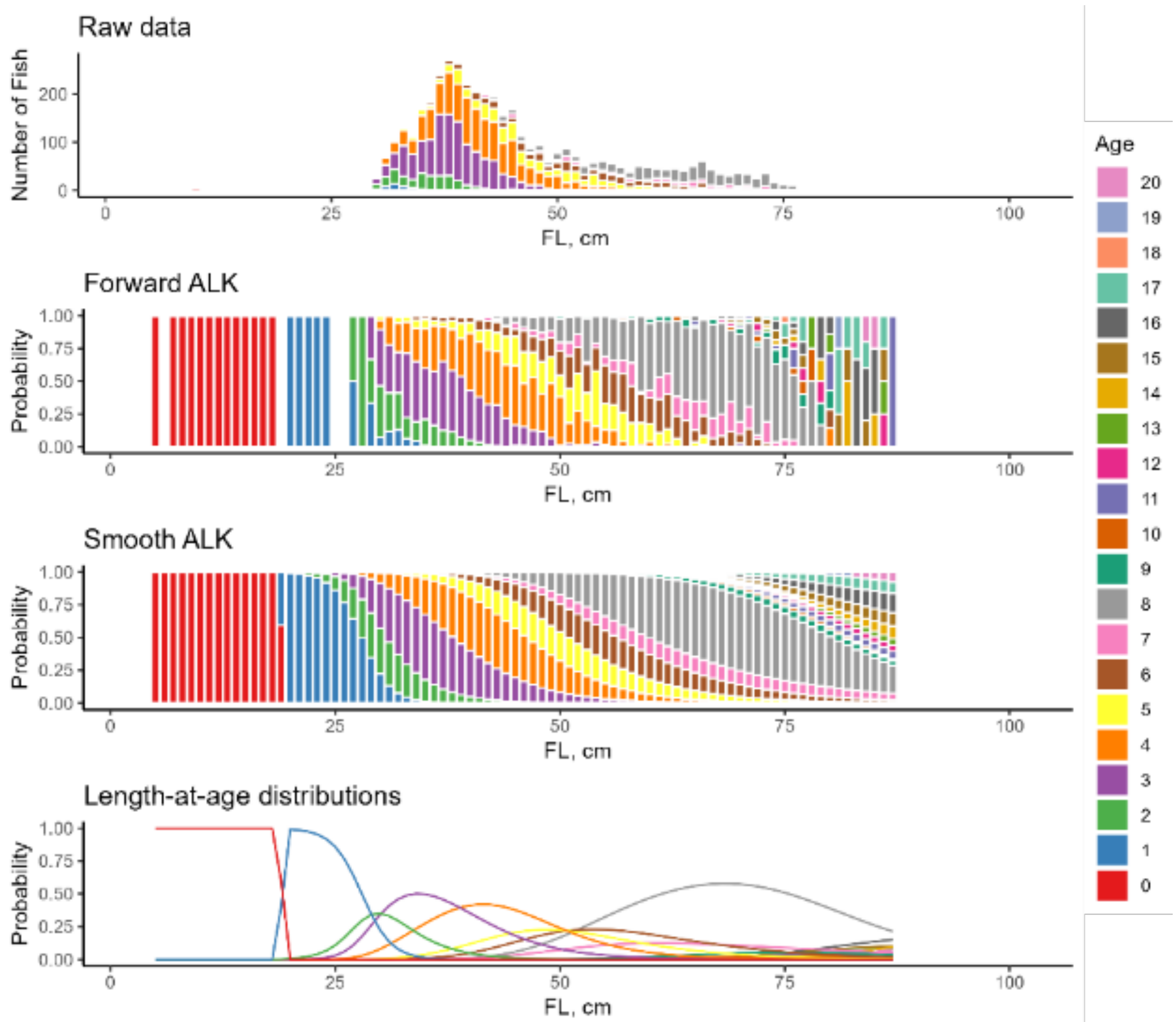

Figure 63. Age data and derived ALKs for 2022 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

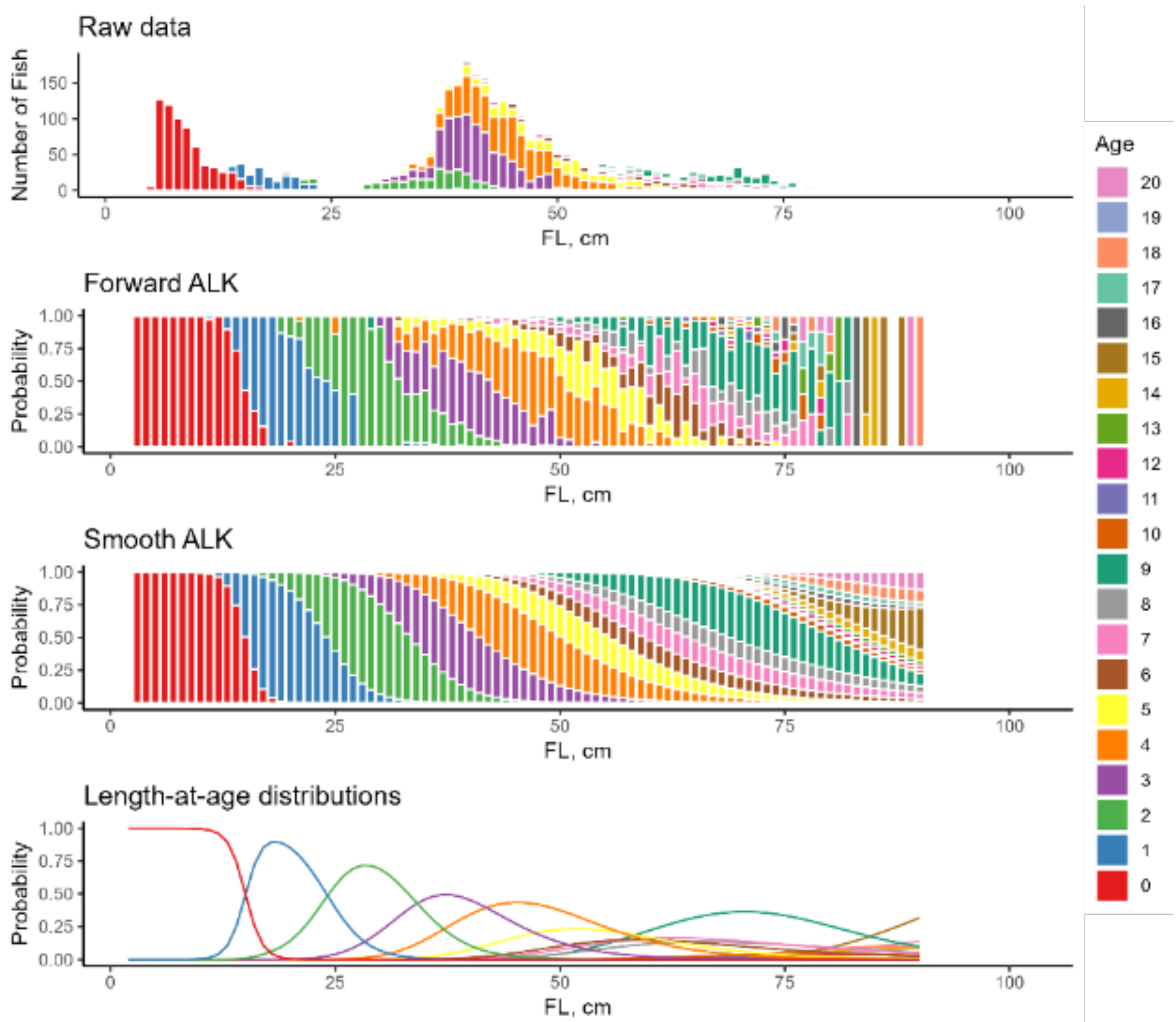

Figure 64. Age data and derived ALKs for 2023 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

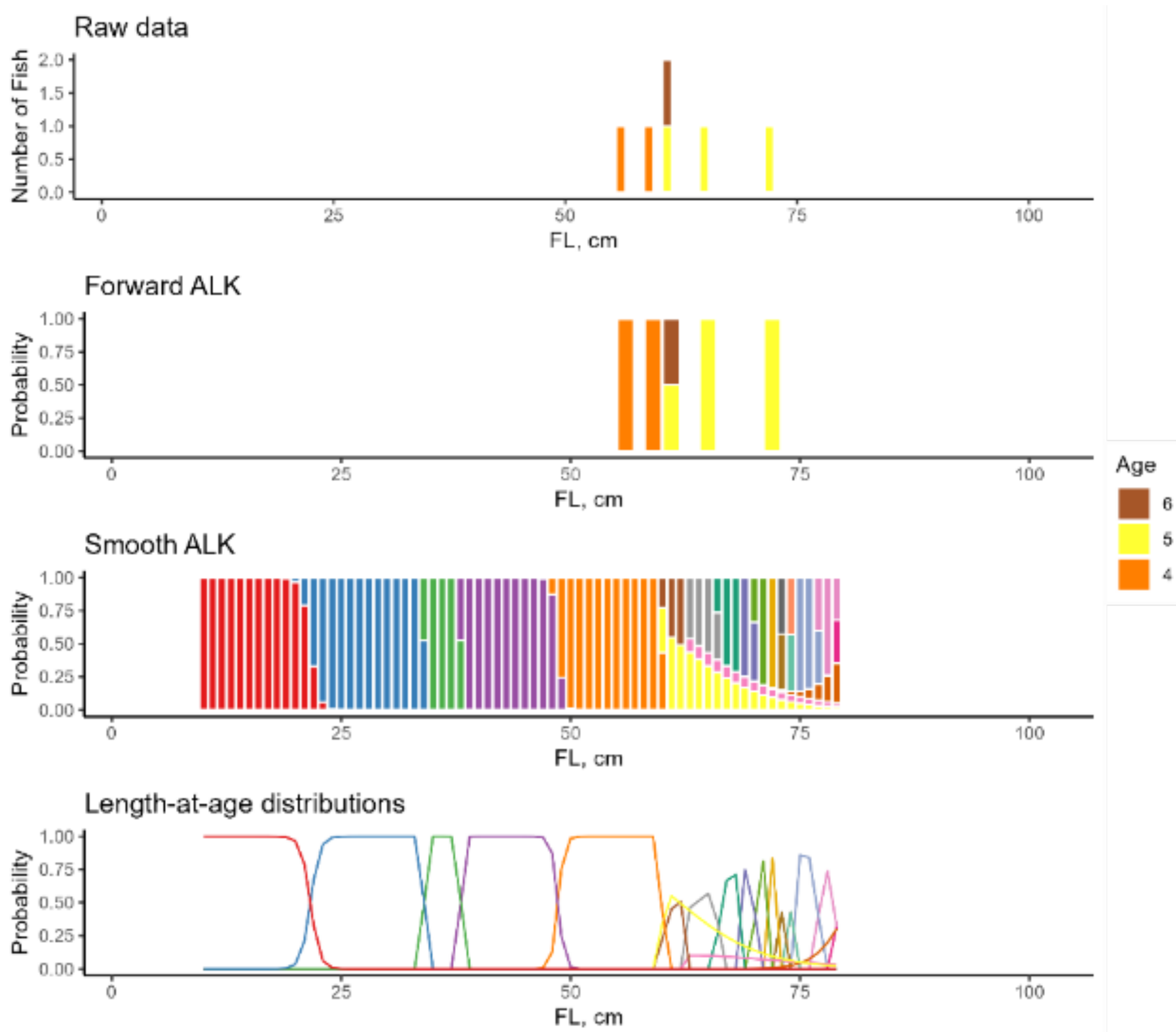

Figure 65. Age data and derived ALKs for 1996 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

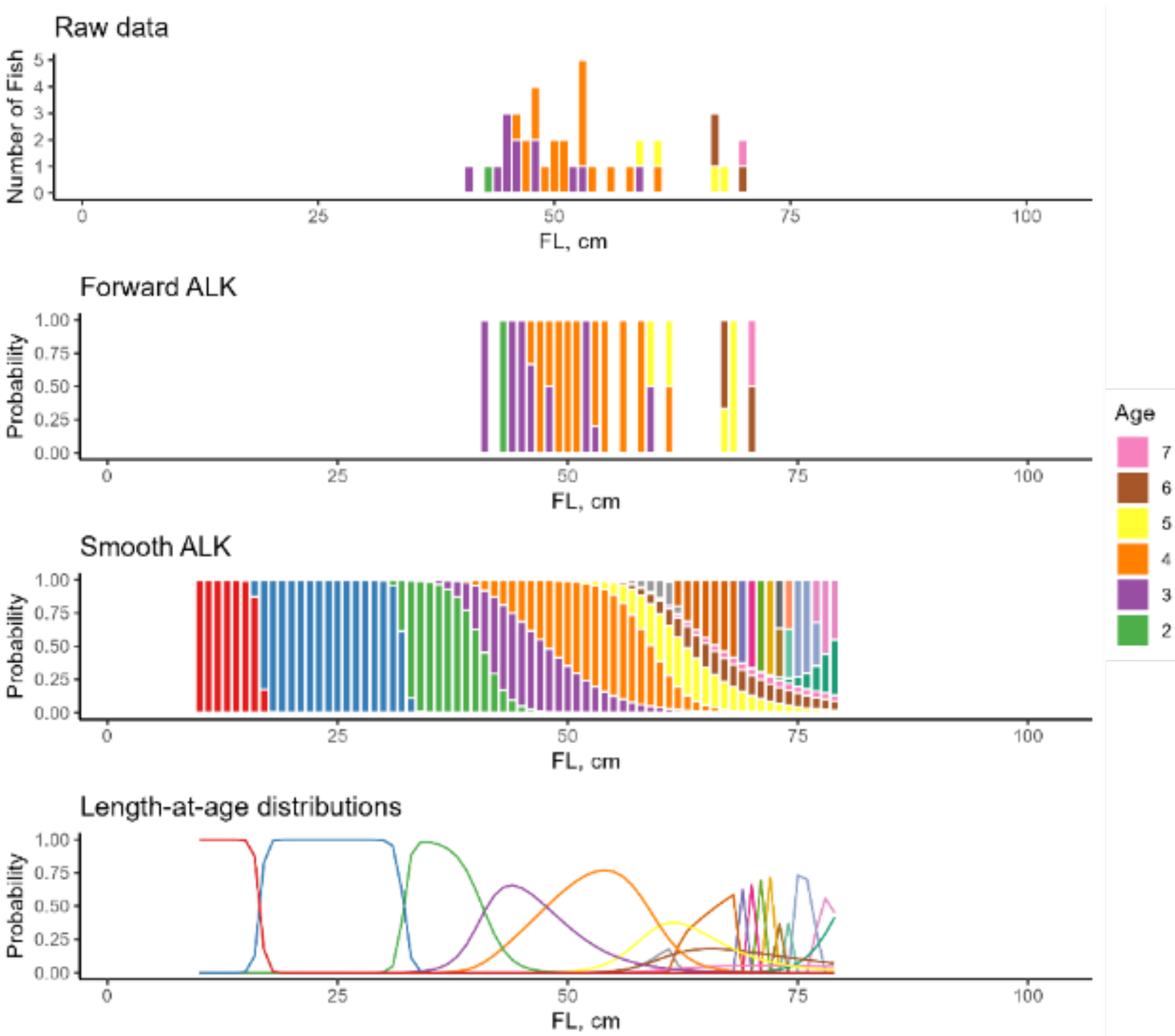

Figure 66. Age data and derived ALKs for 1997 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

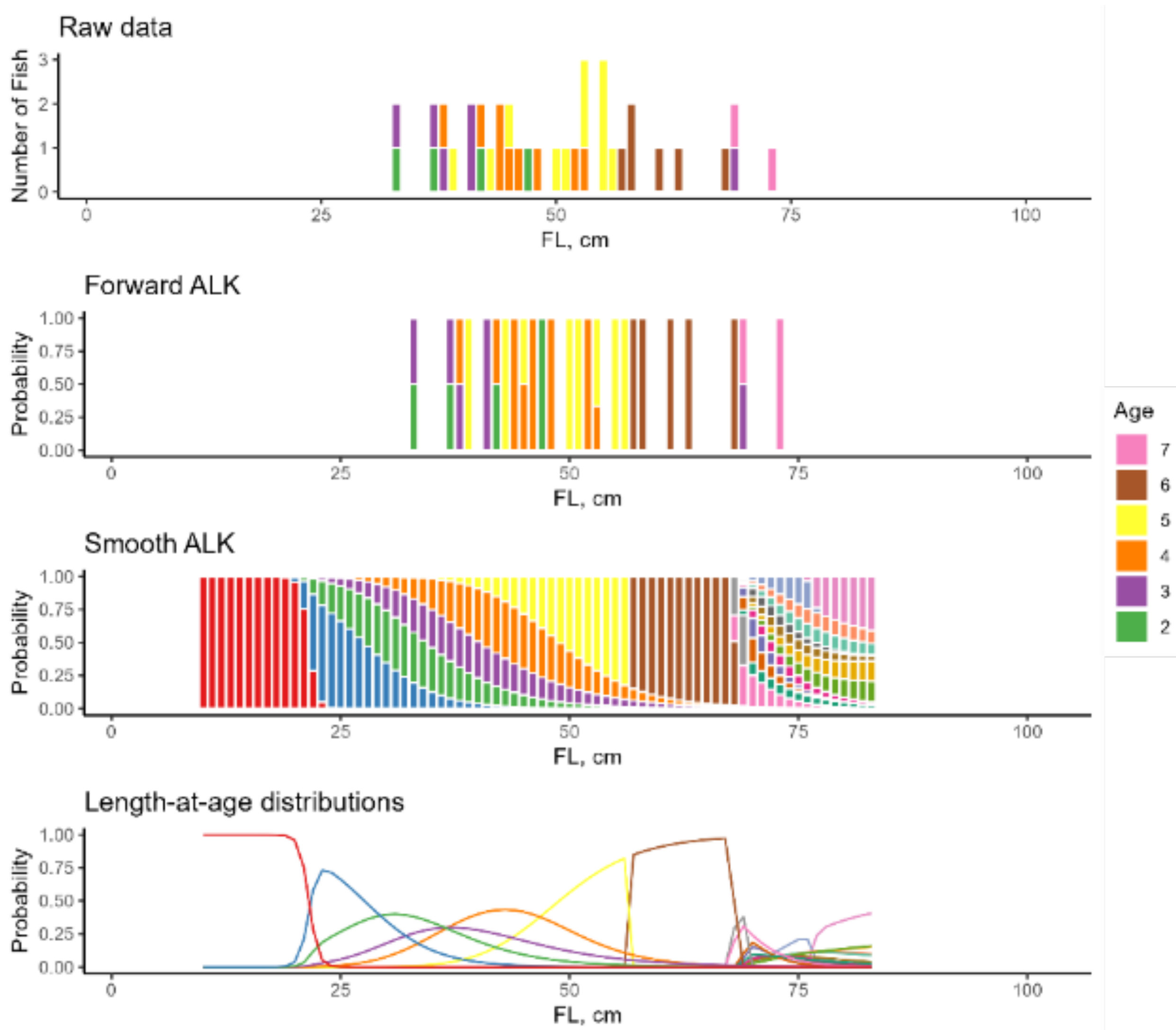

Figure 67. Age data and derived ALKs for 1998 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

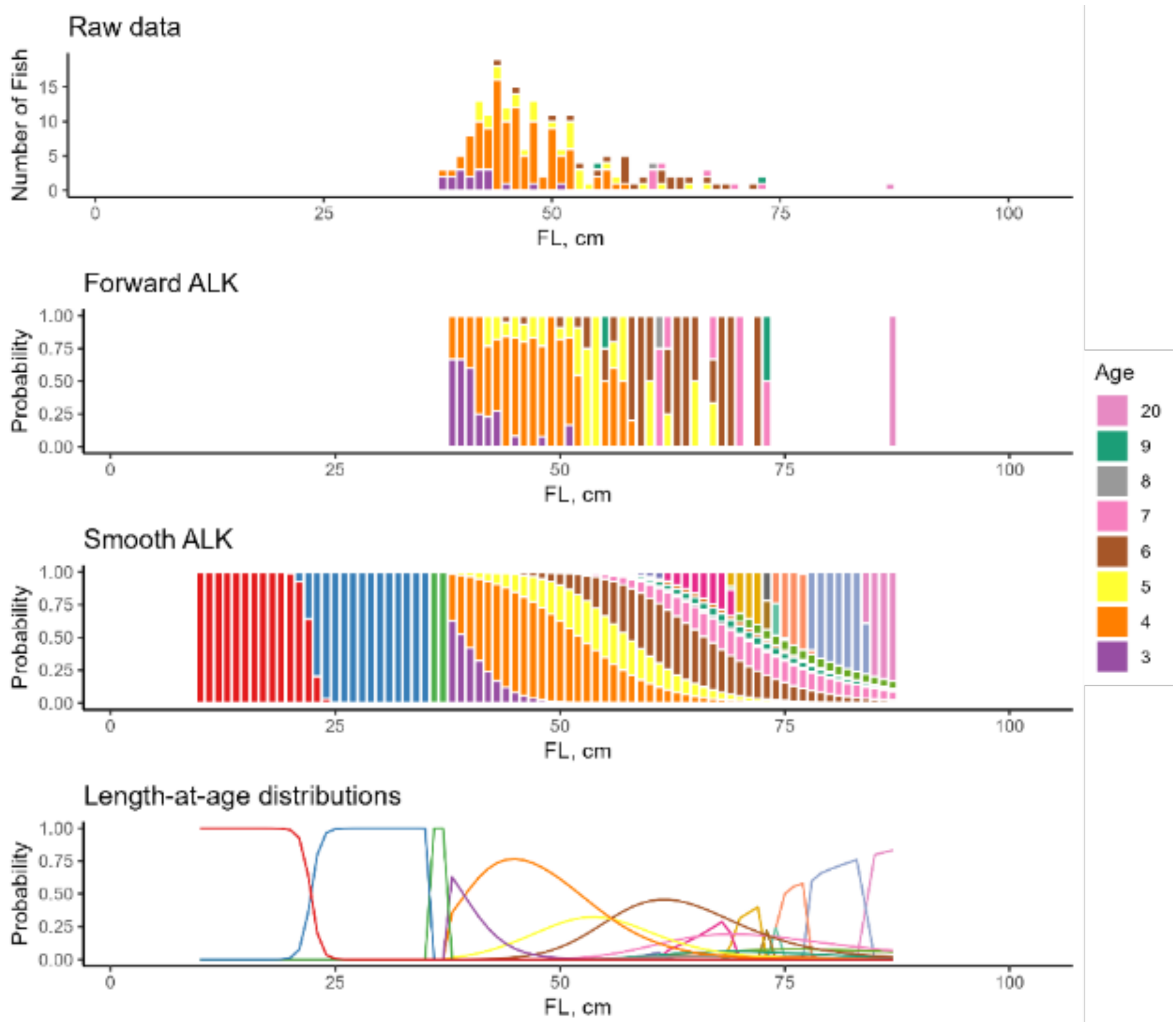

Figure 68. Age data and derived ALKs for 1999 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

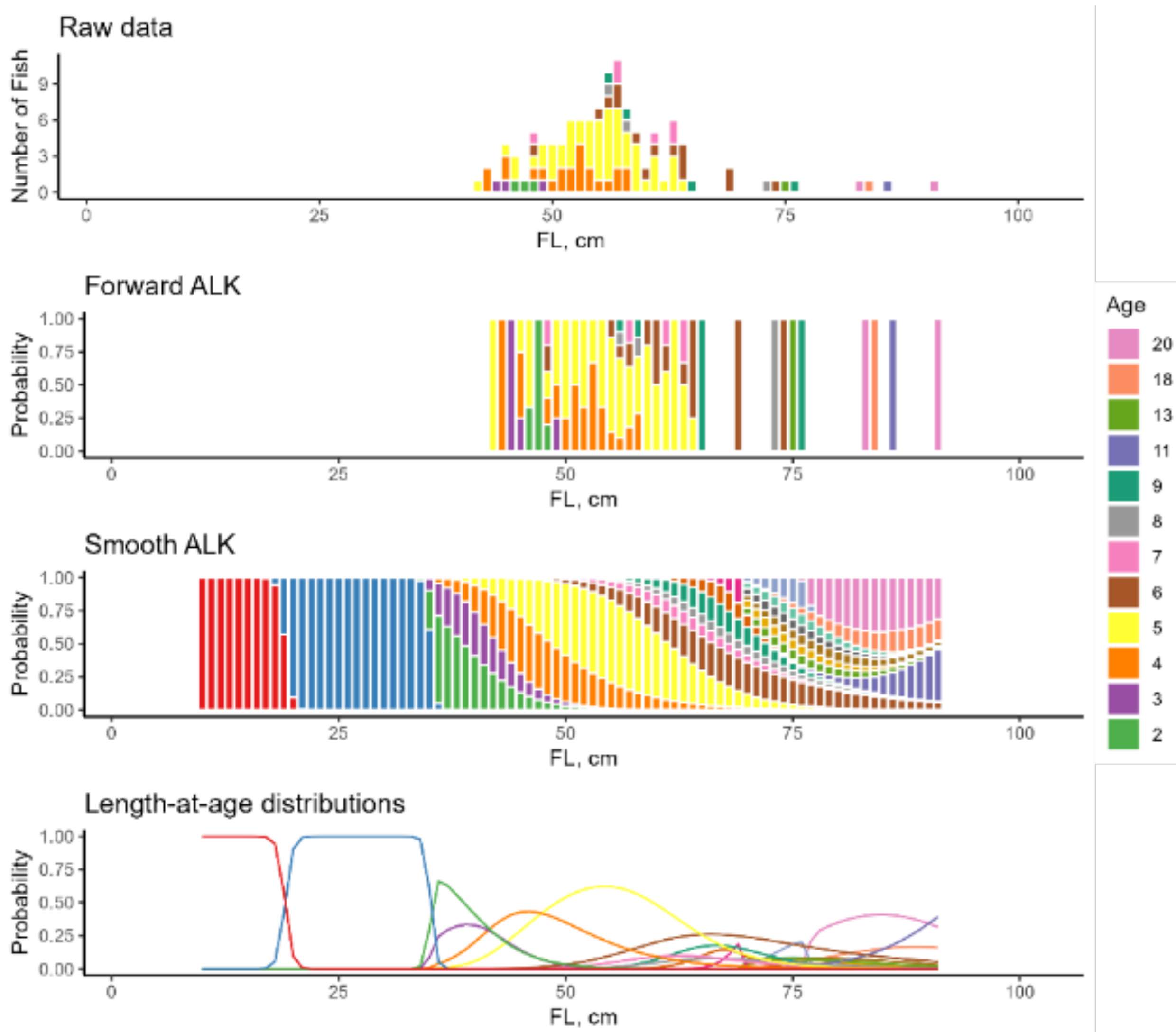

Figure 69. Age data and derived ALKs for 2000 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

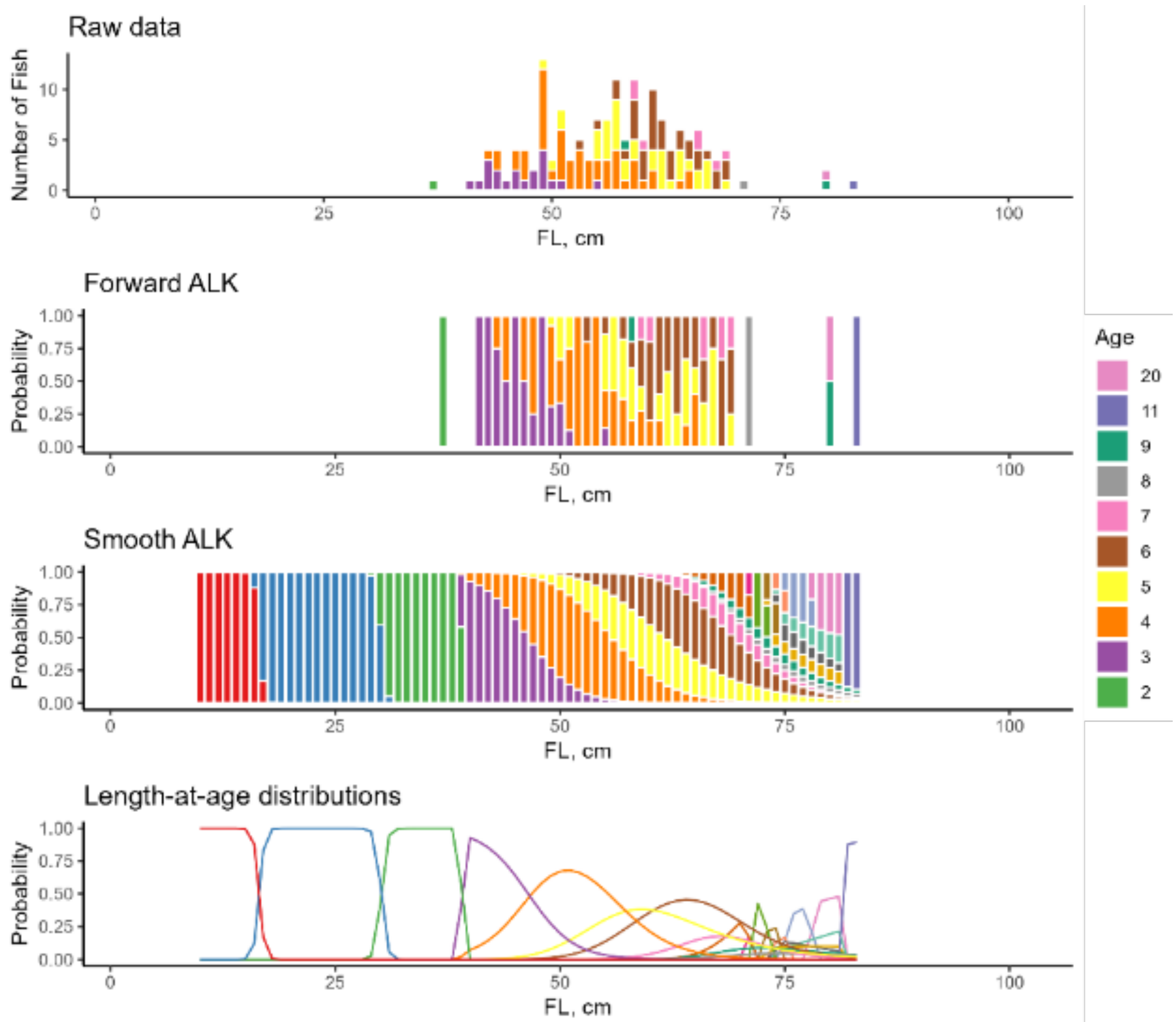

Figure 70. Age data and derived ALKs for 2001 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

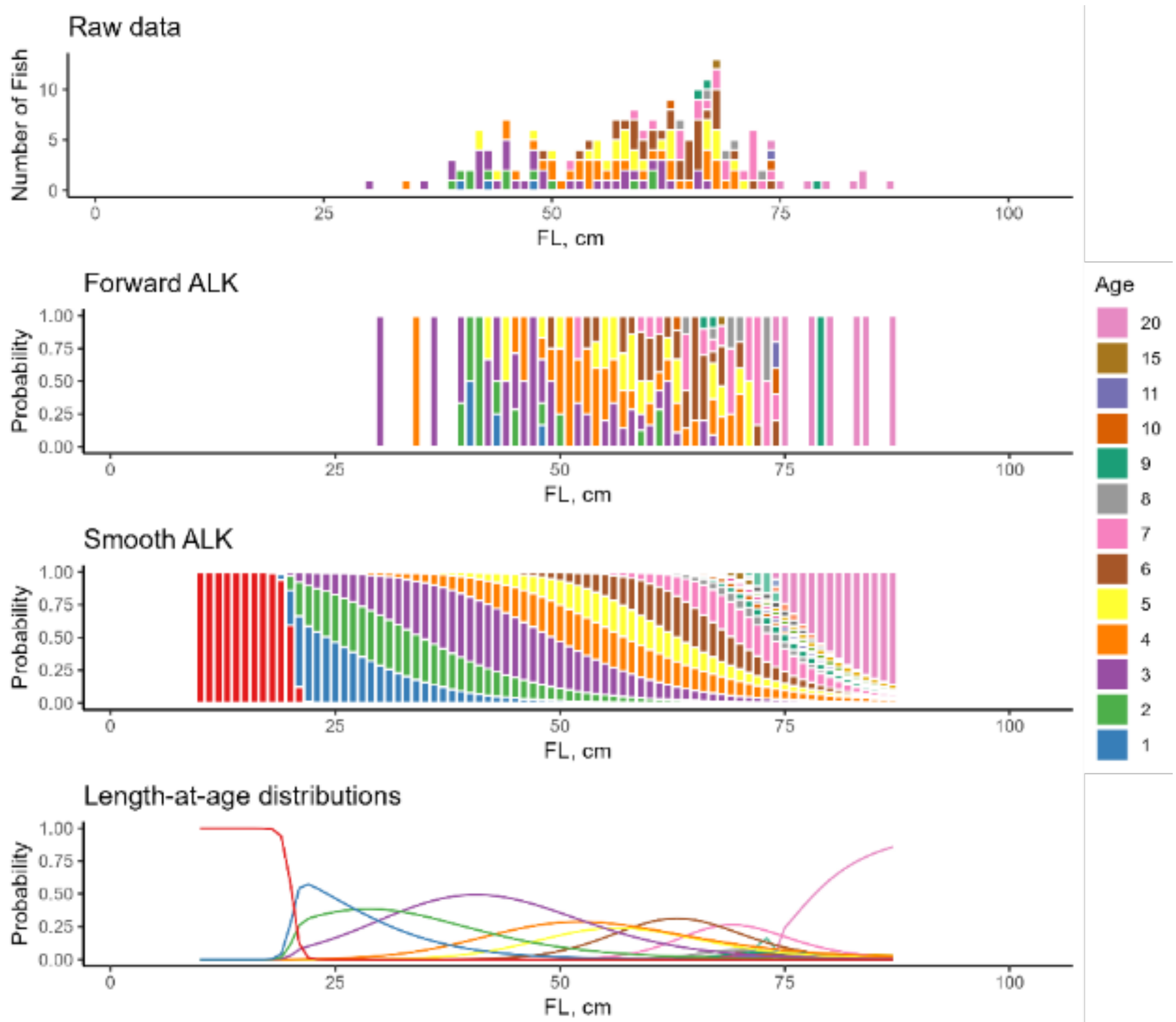

Figure 71. Age data and derived ALKs for 2002 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

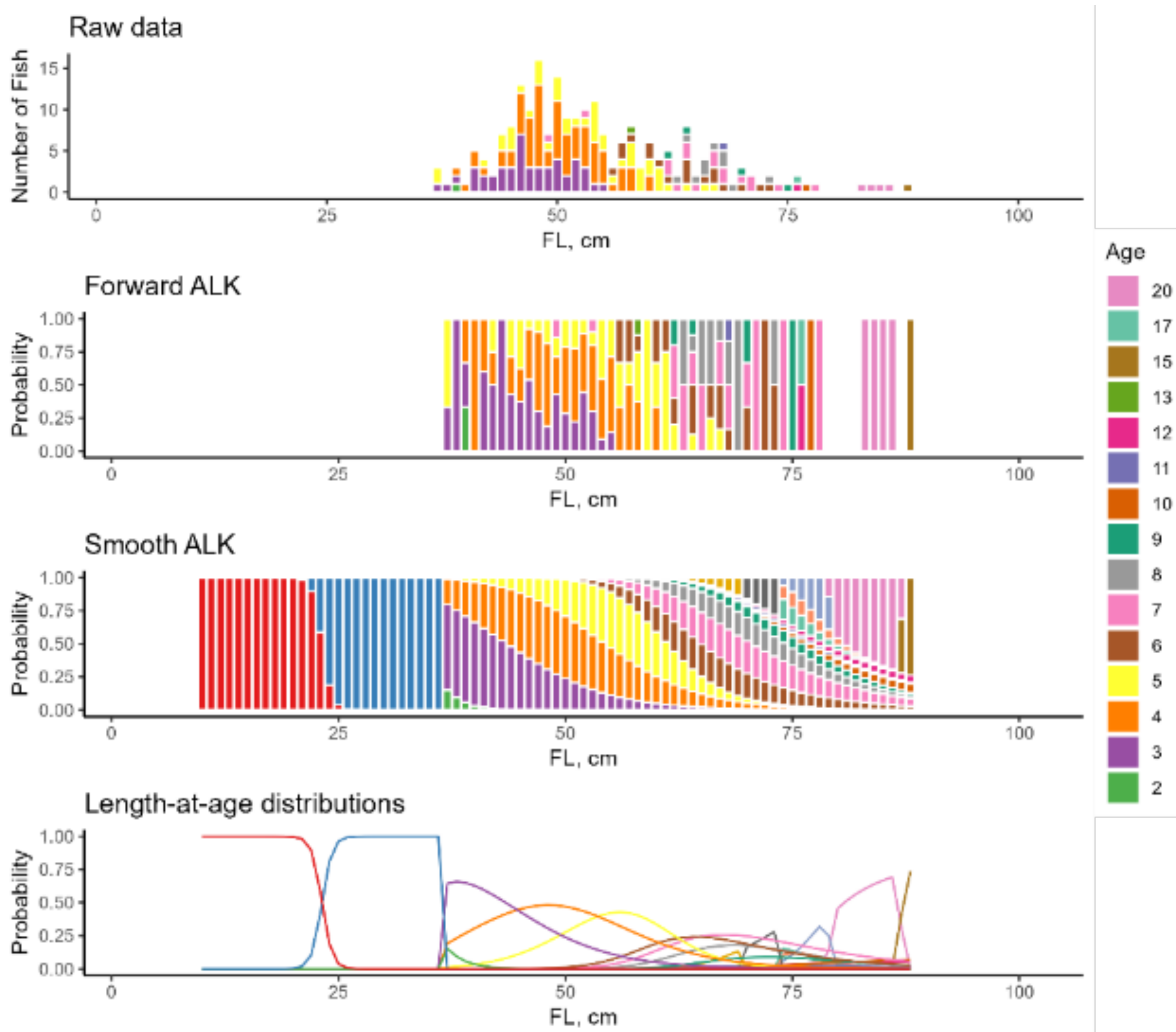

Figure 72. Age data and derived ALKs for 2003 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

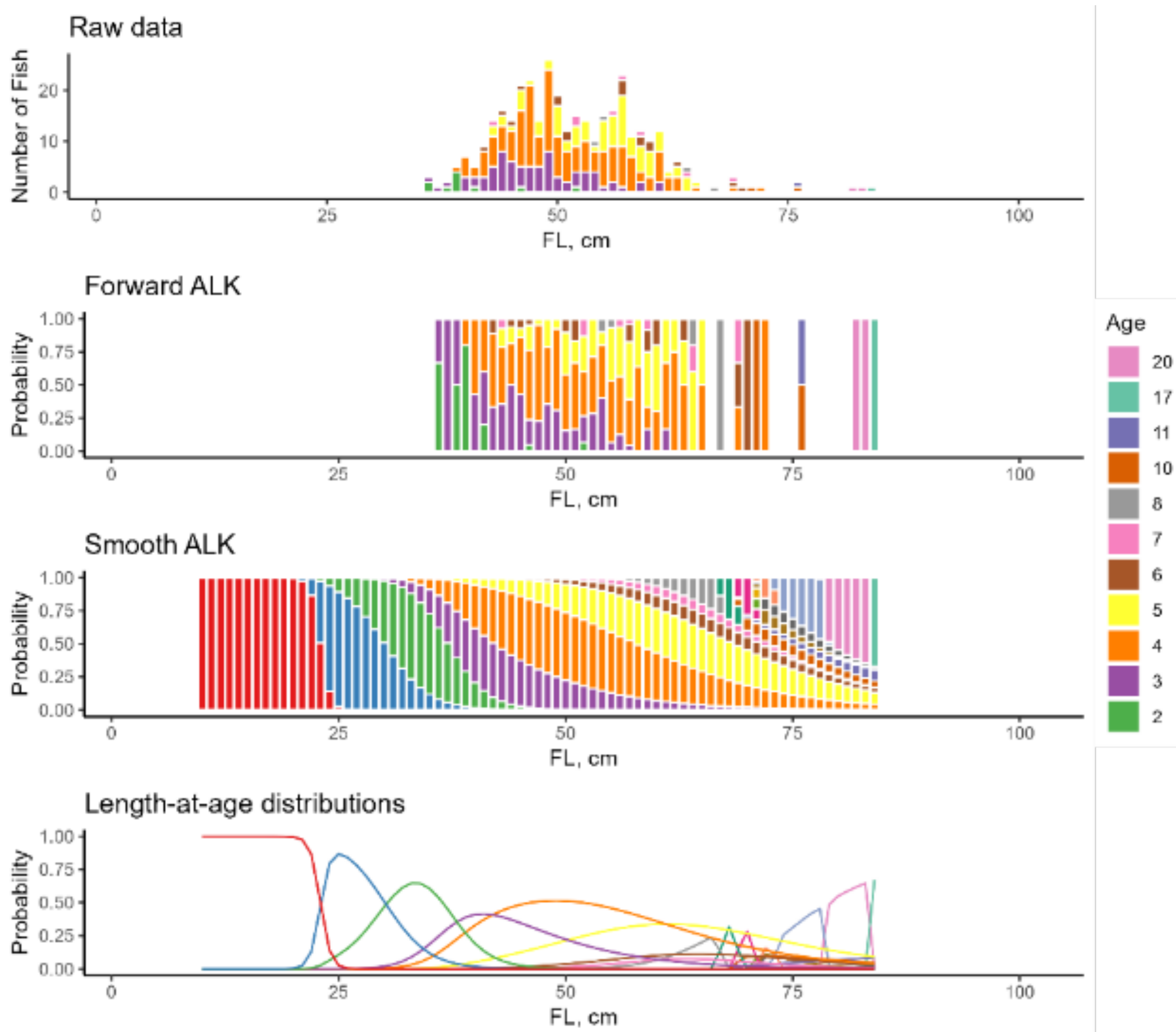

Figure 73. Age data and derived ALKs for 2004 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

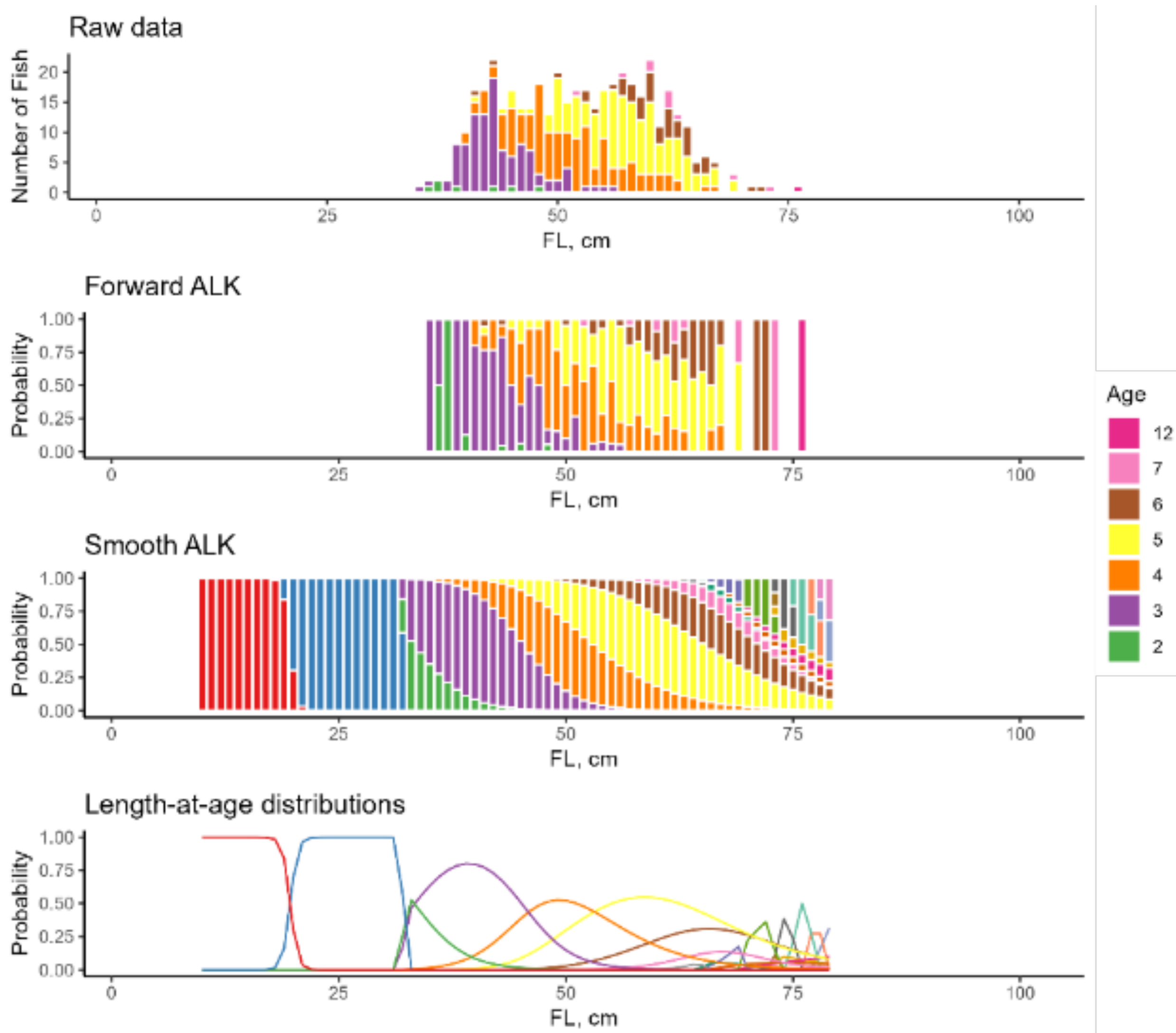

Figure 74. Age data and derived ALKs for 2005 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

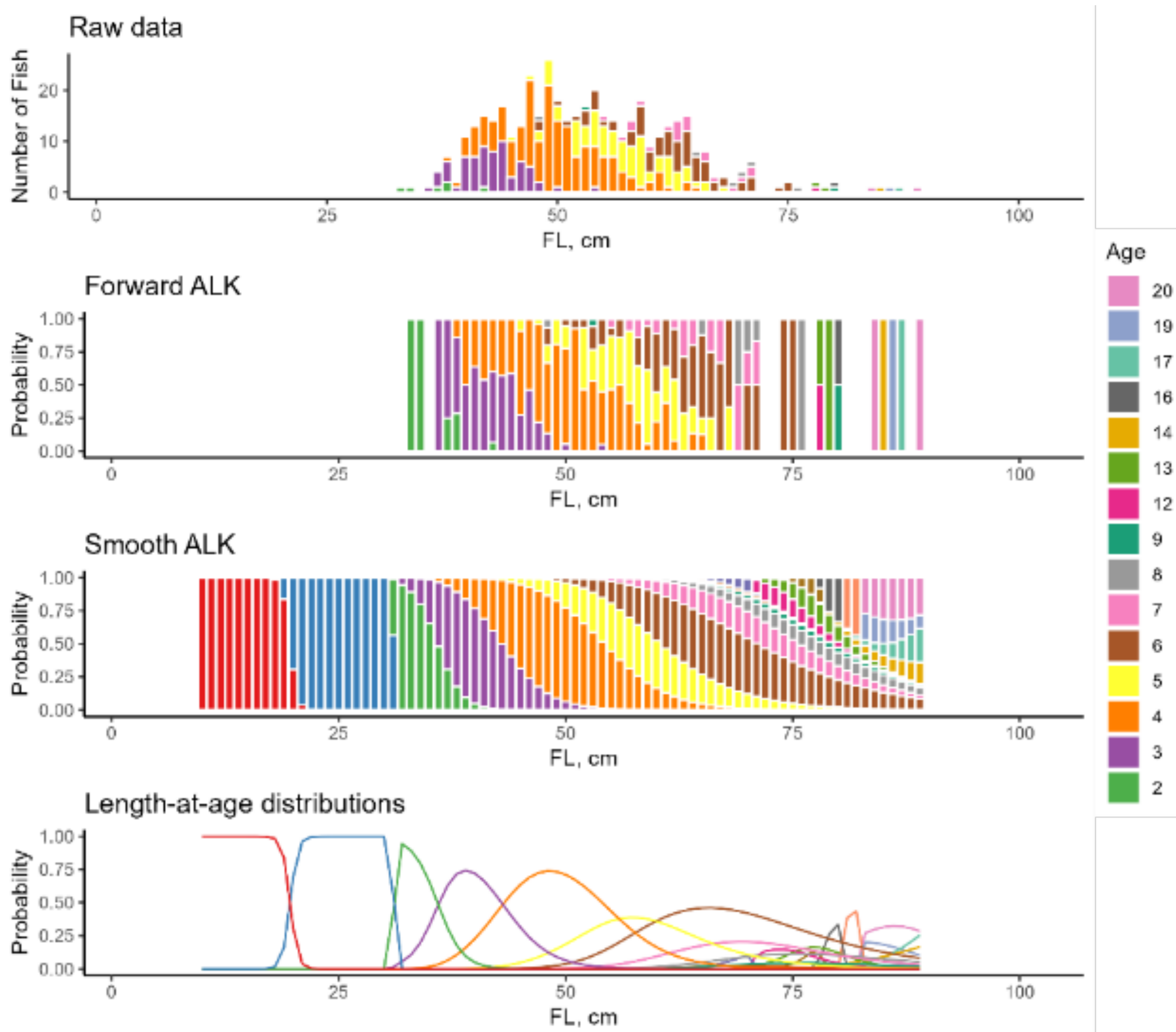

Figure 75. Age data and derived ALKs for 2006 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

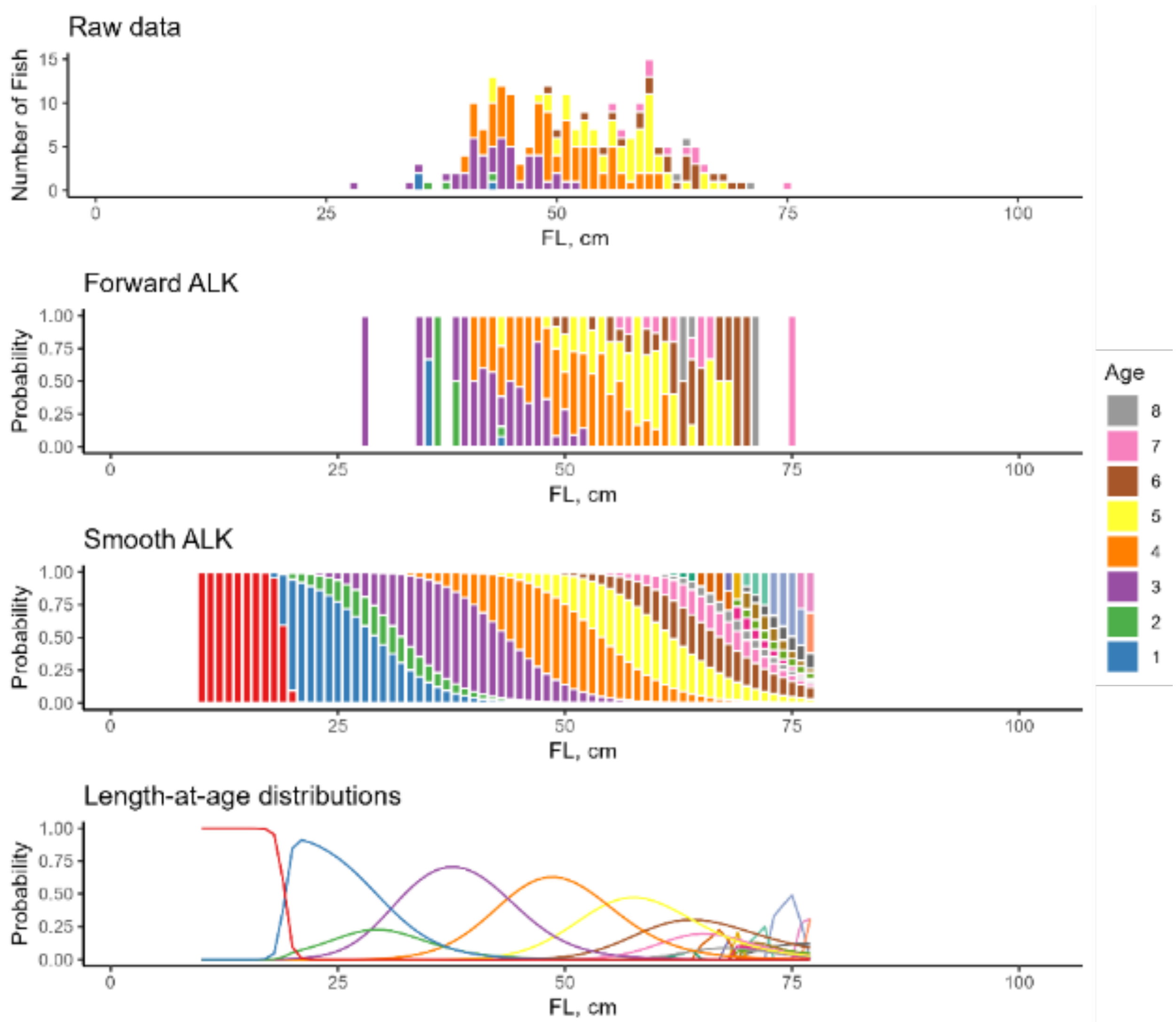

Figure 76. Age data and derived ALKs for 2007 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

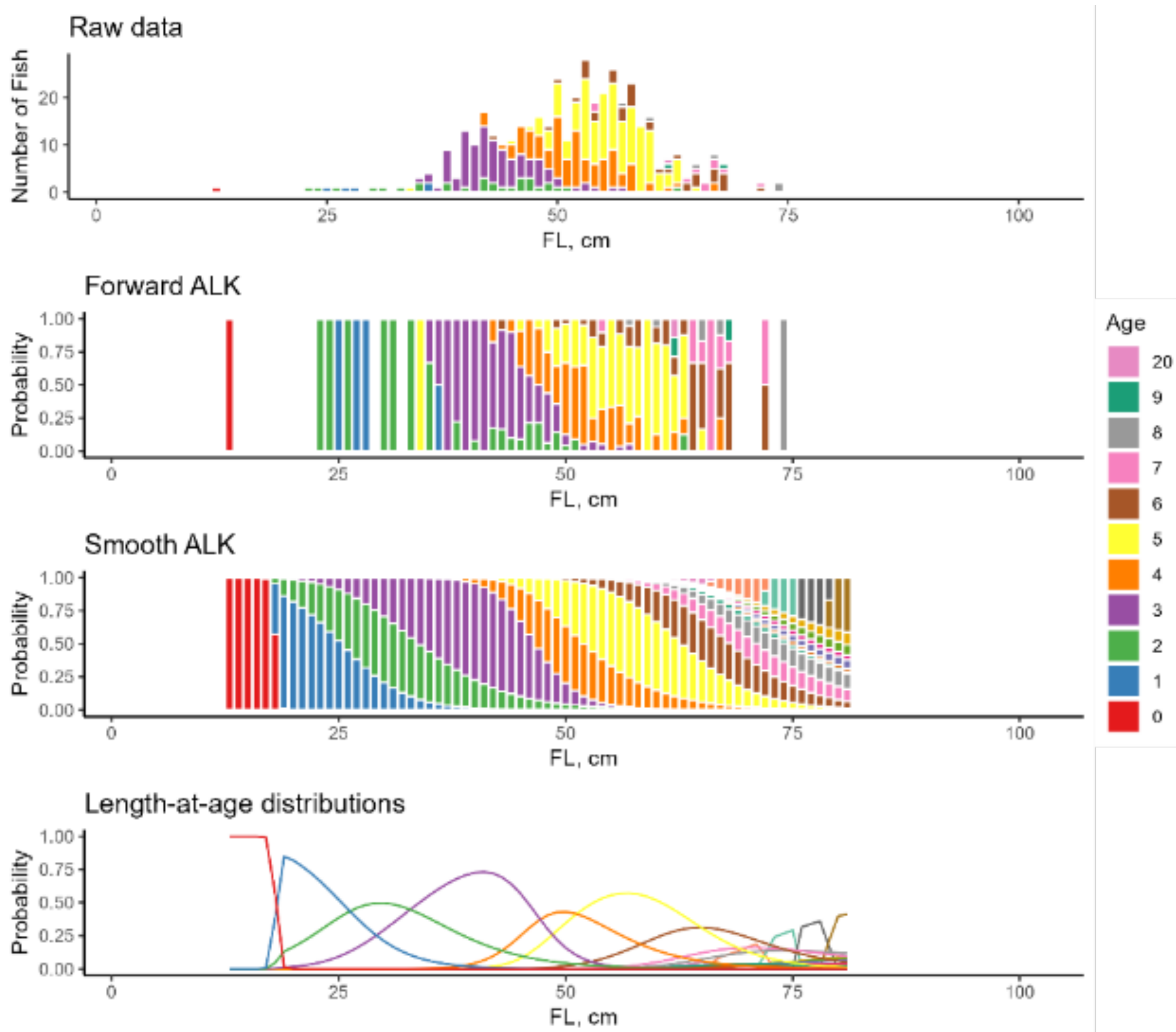

Figure 77. Age data and derived ALKs for 2008 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

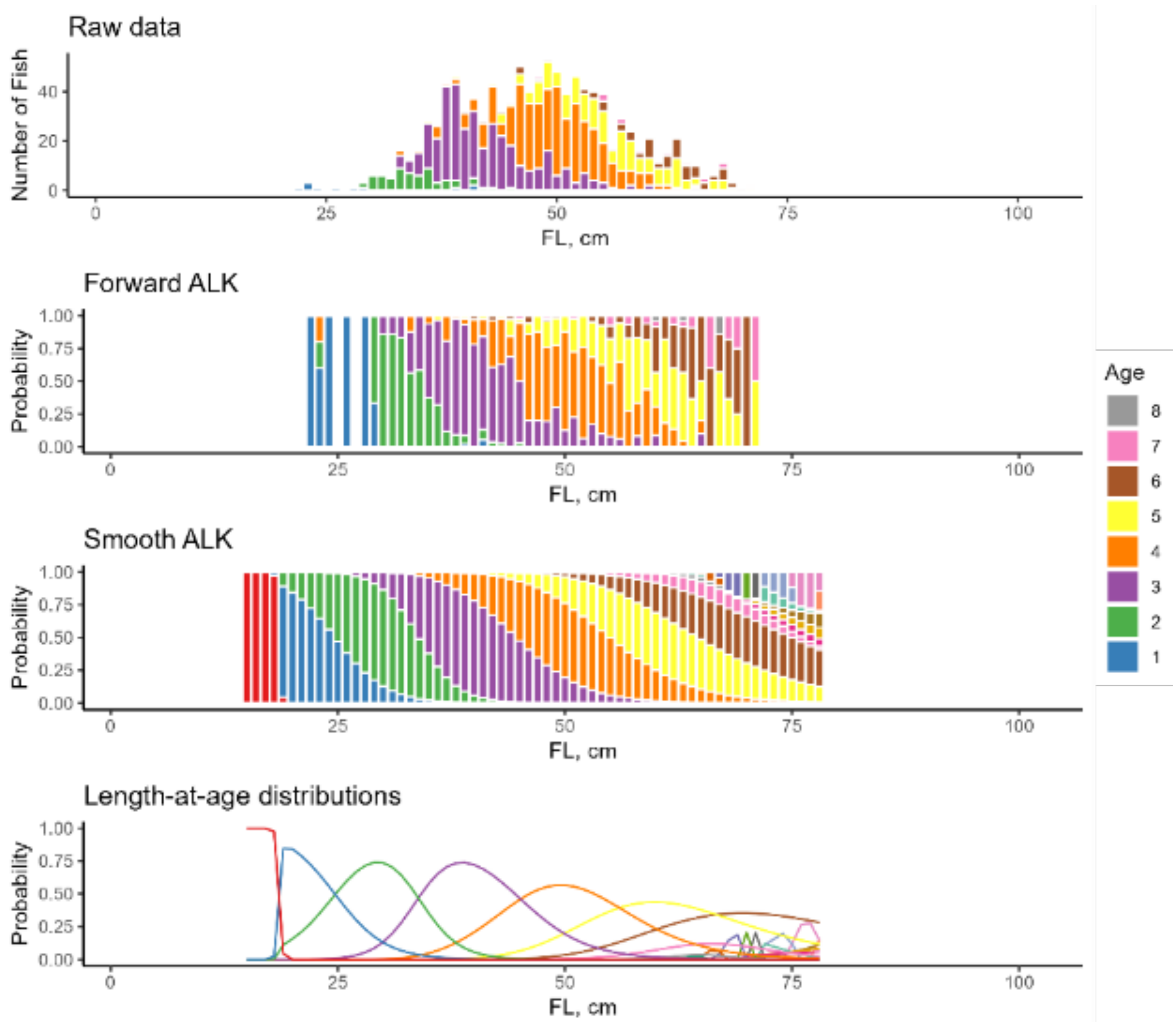

Figure 78. Age data and derived ALKs for 2009 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

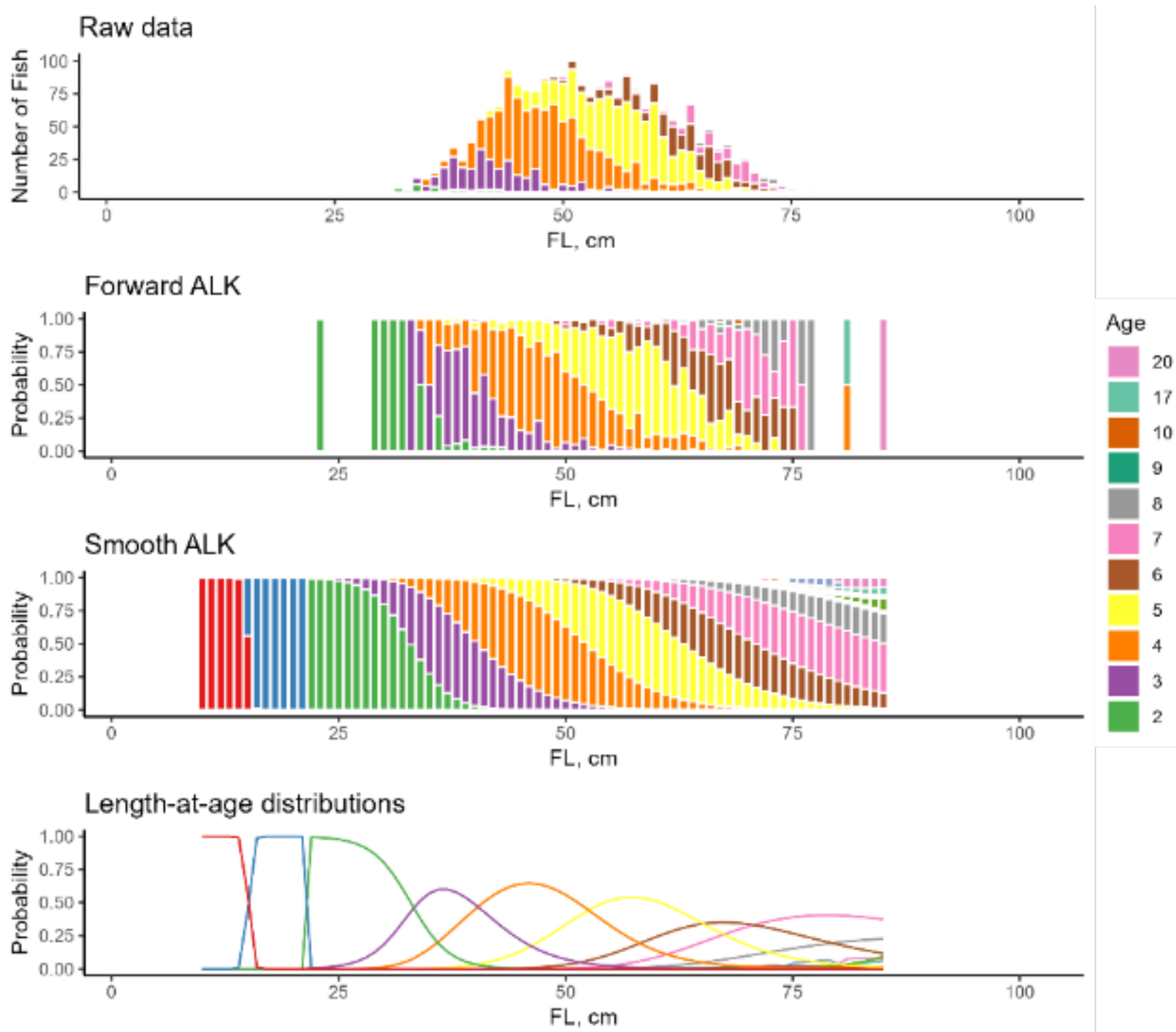

Figure 79. Age data and derived ALKs for 2010 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

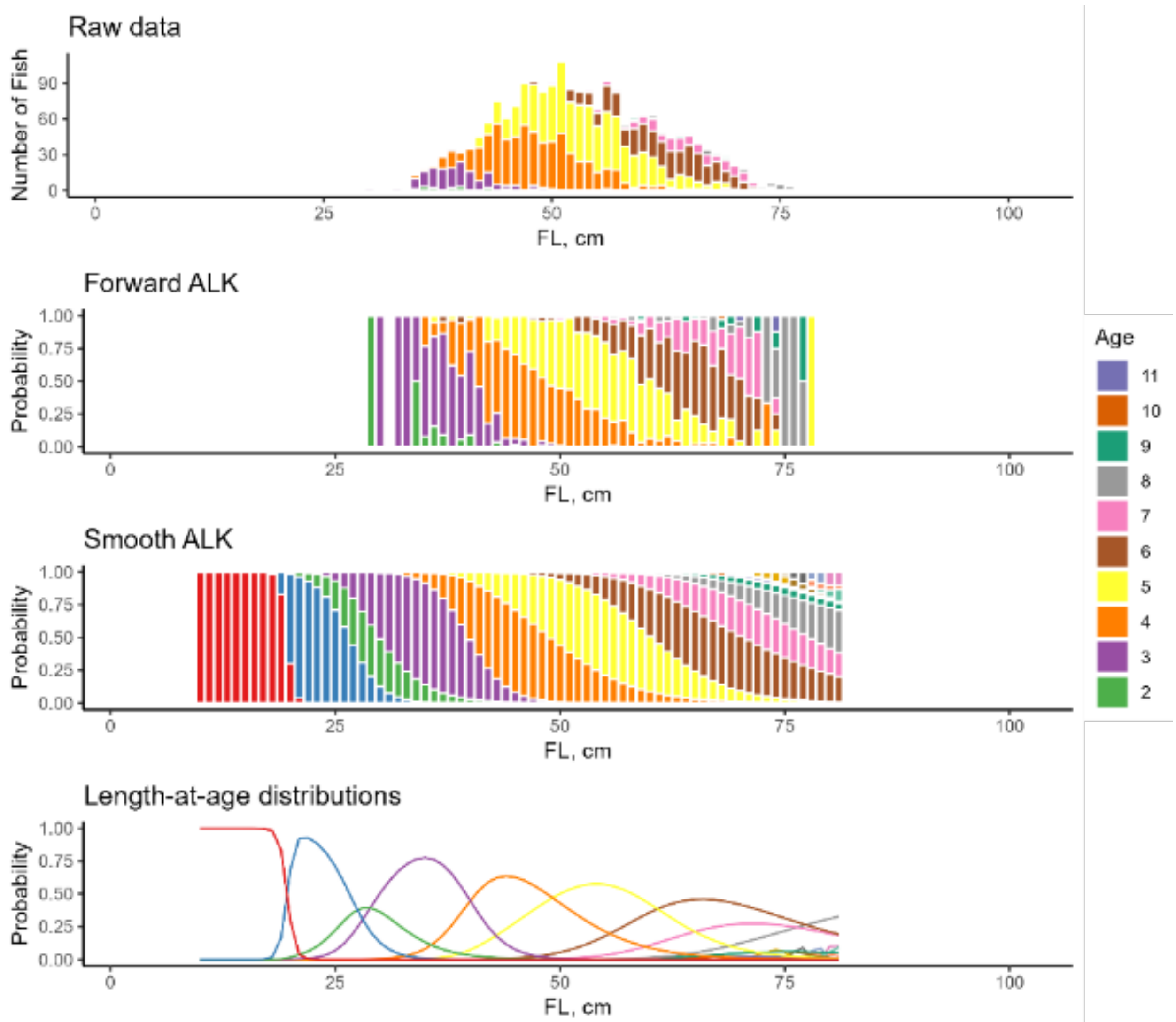

Figure 80. Age data and derived ALKs for 2011 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

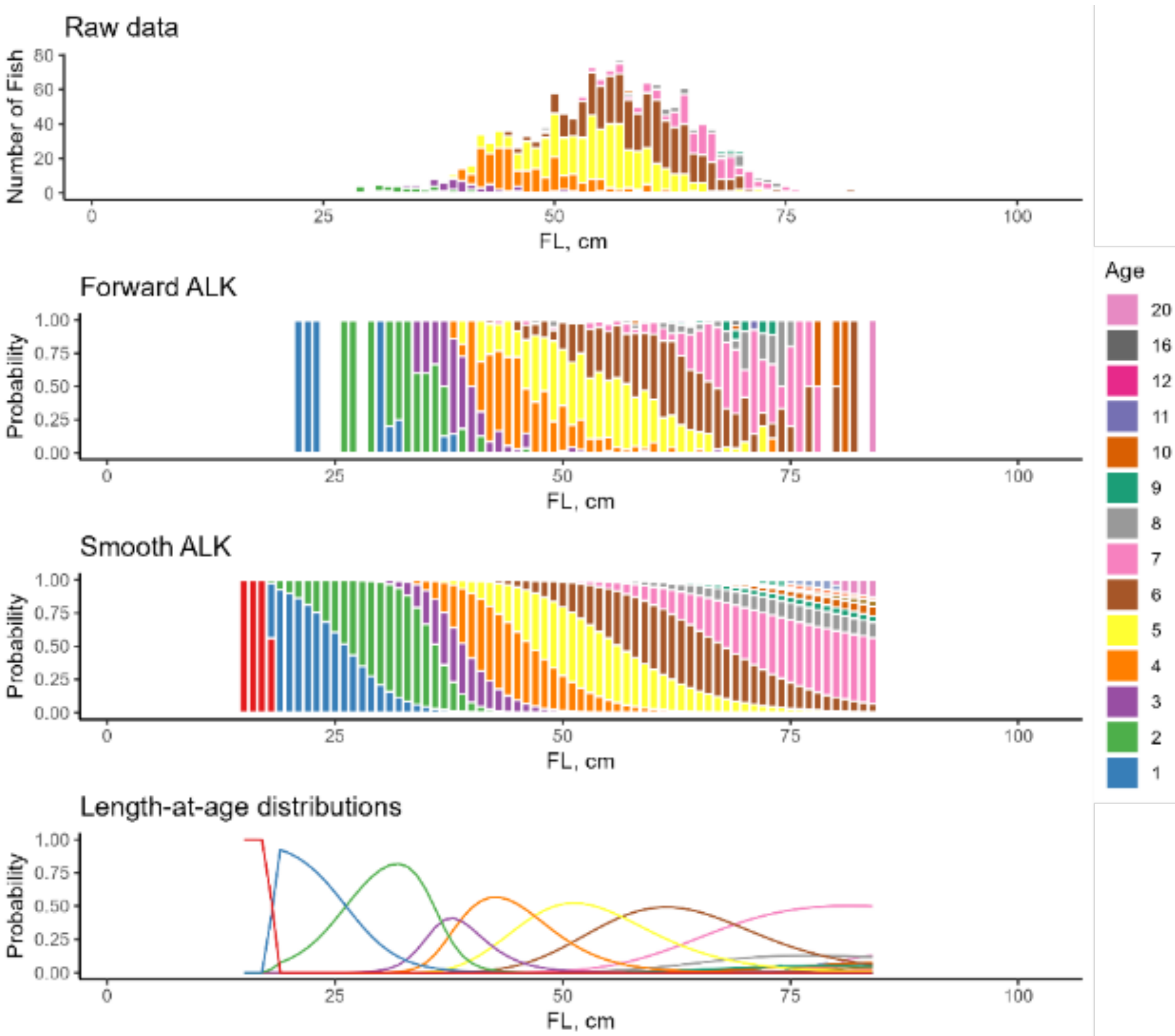

Figure 81. Age data and derived ALKs for 2012 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

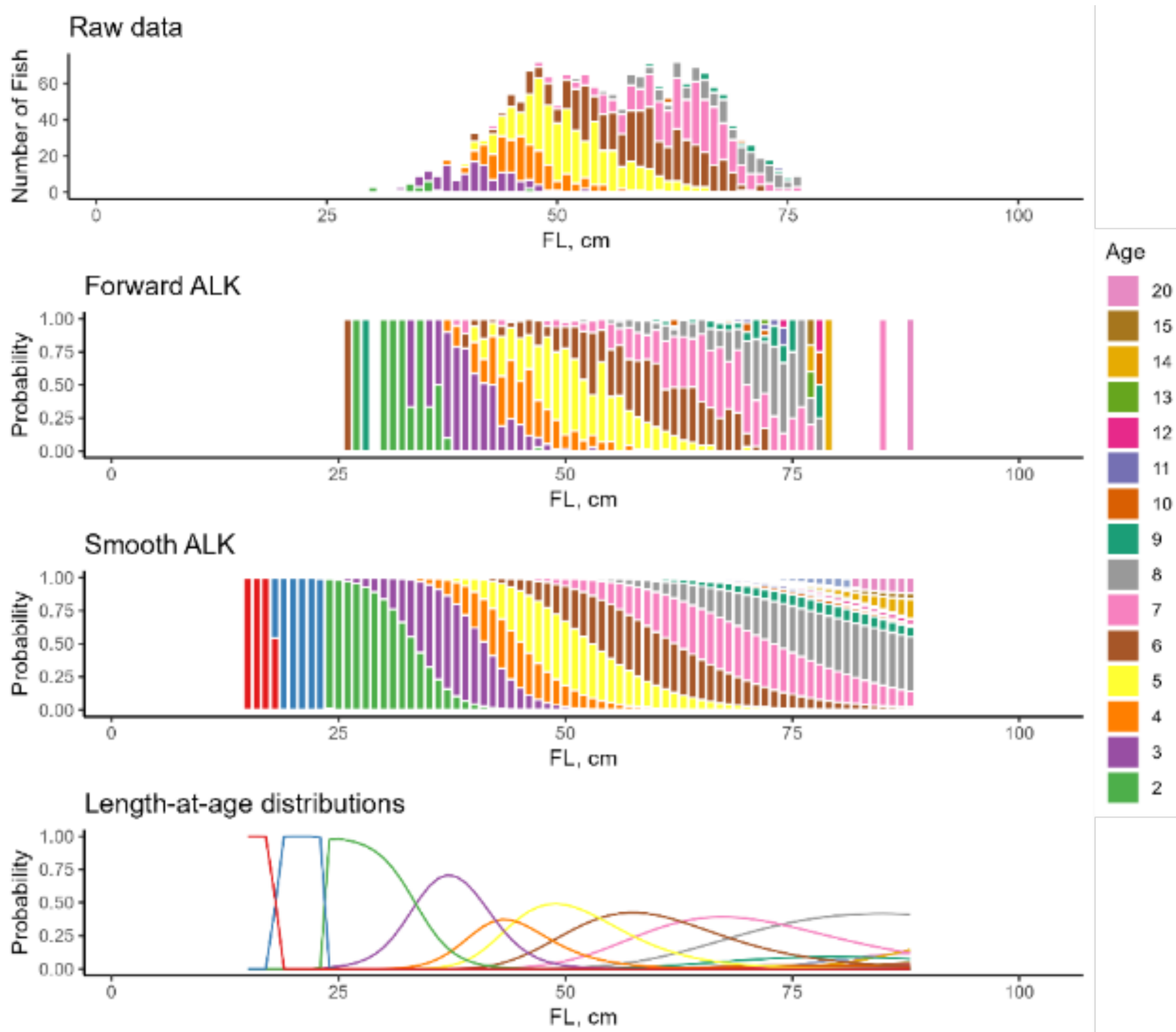

Figure 82. Age data and derived ALKs for 2013 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

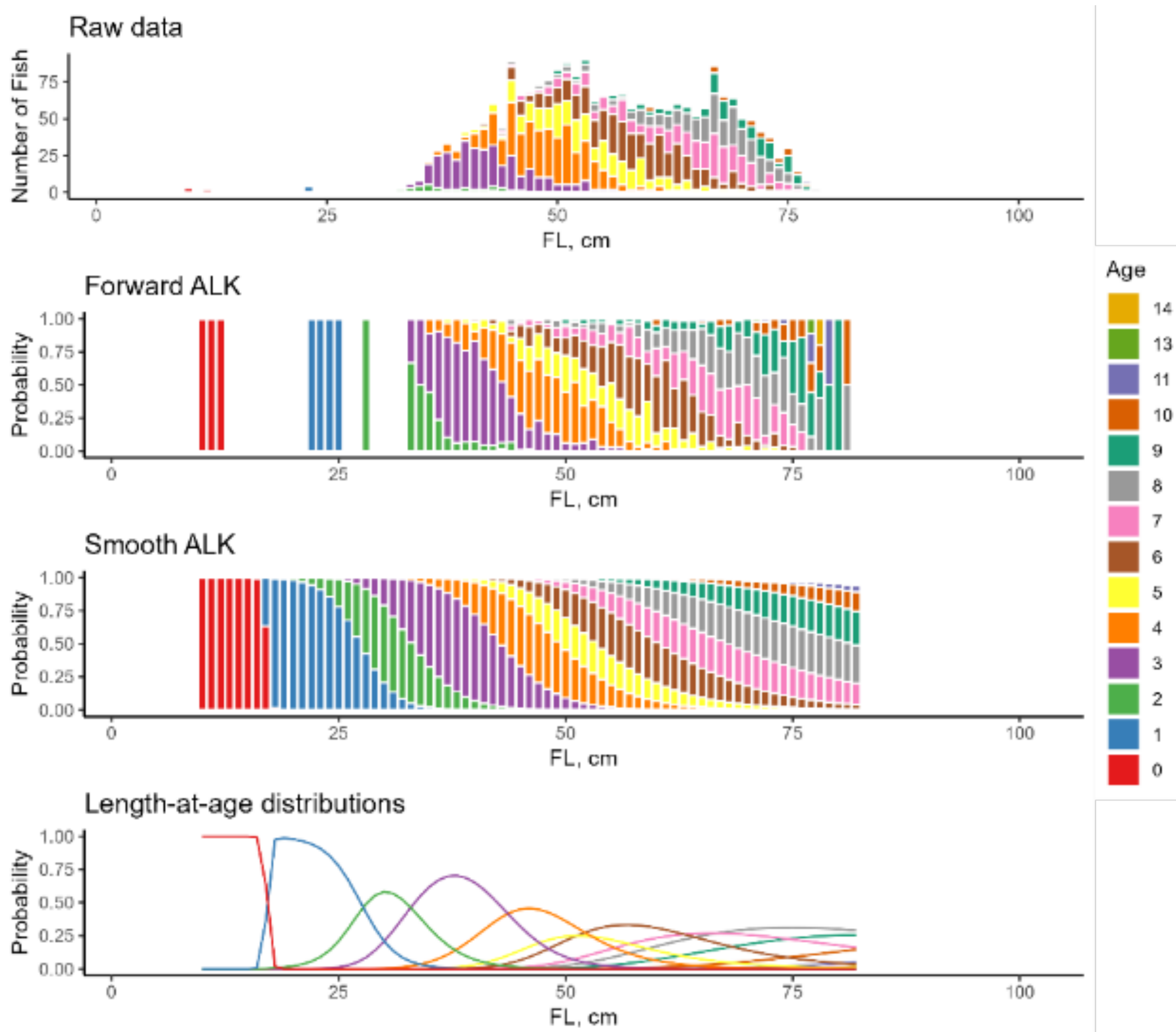

Figure 83. Age data and derived ALKs for 2014 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

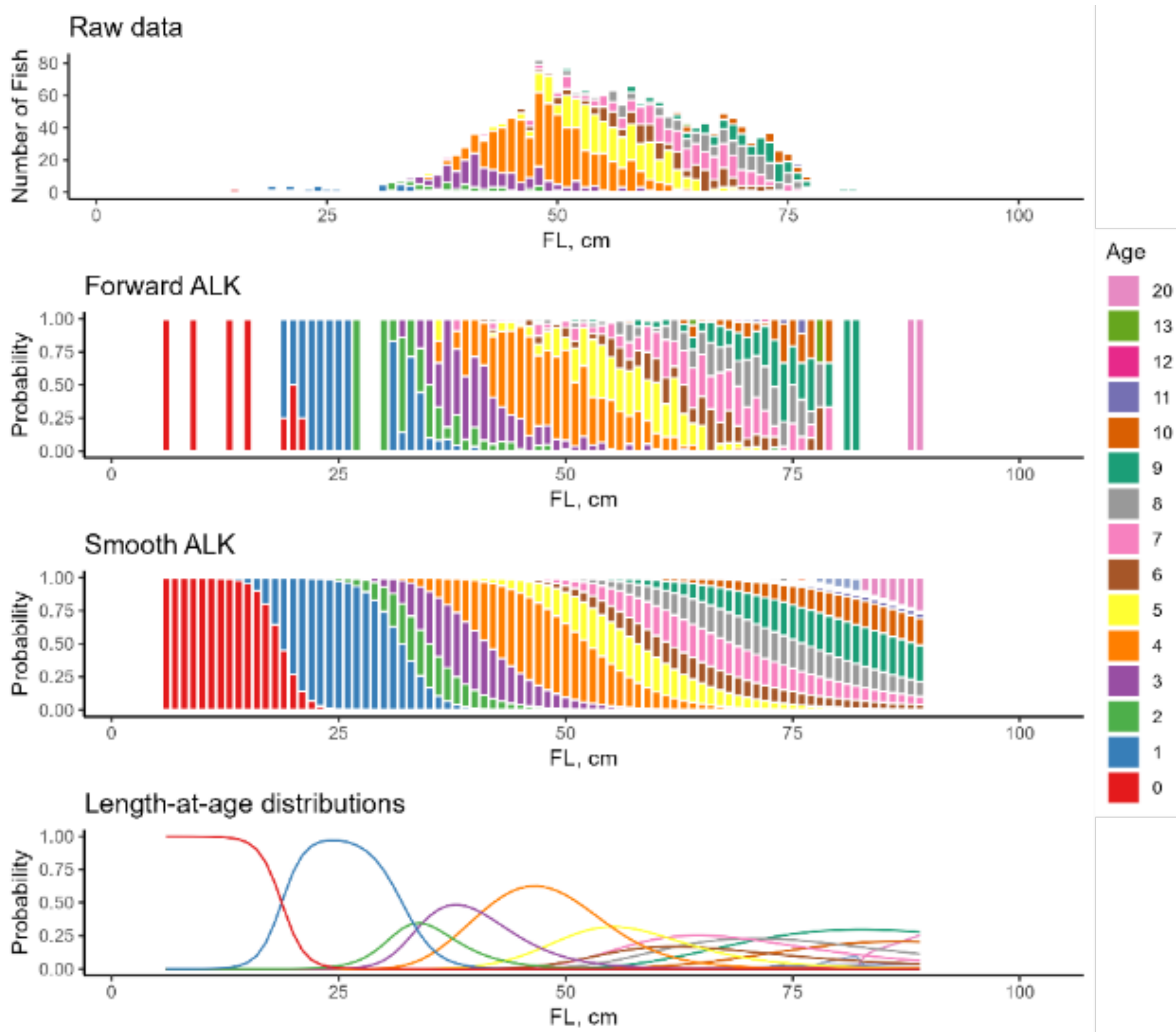

Figure 84. Age data and derived ALKs for 2015 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

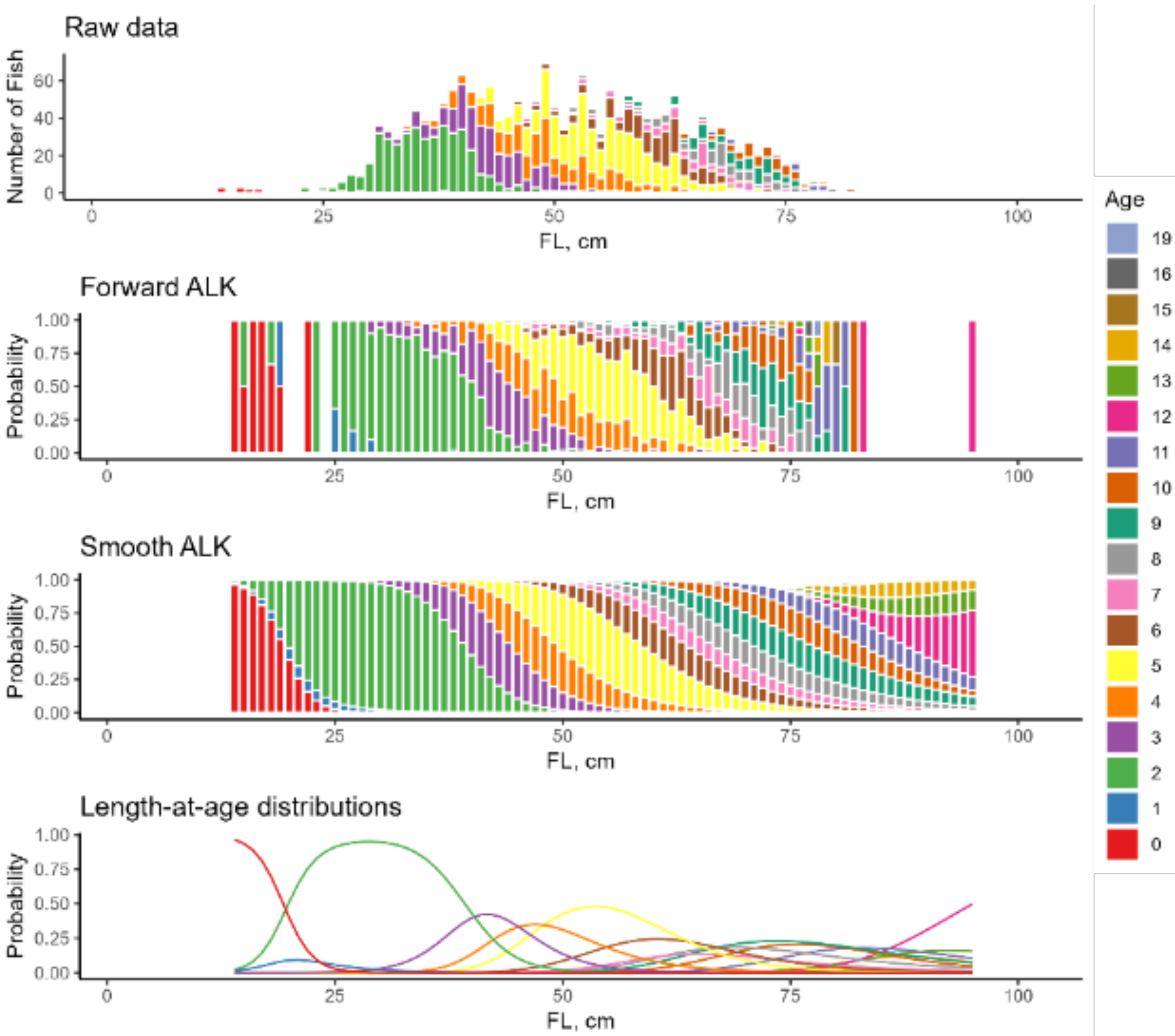

Figure 85. Age data and derived ALKs for 2016 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

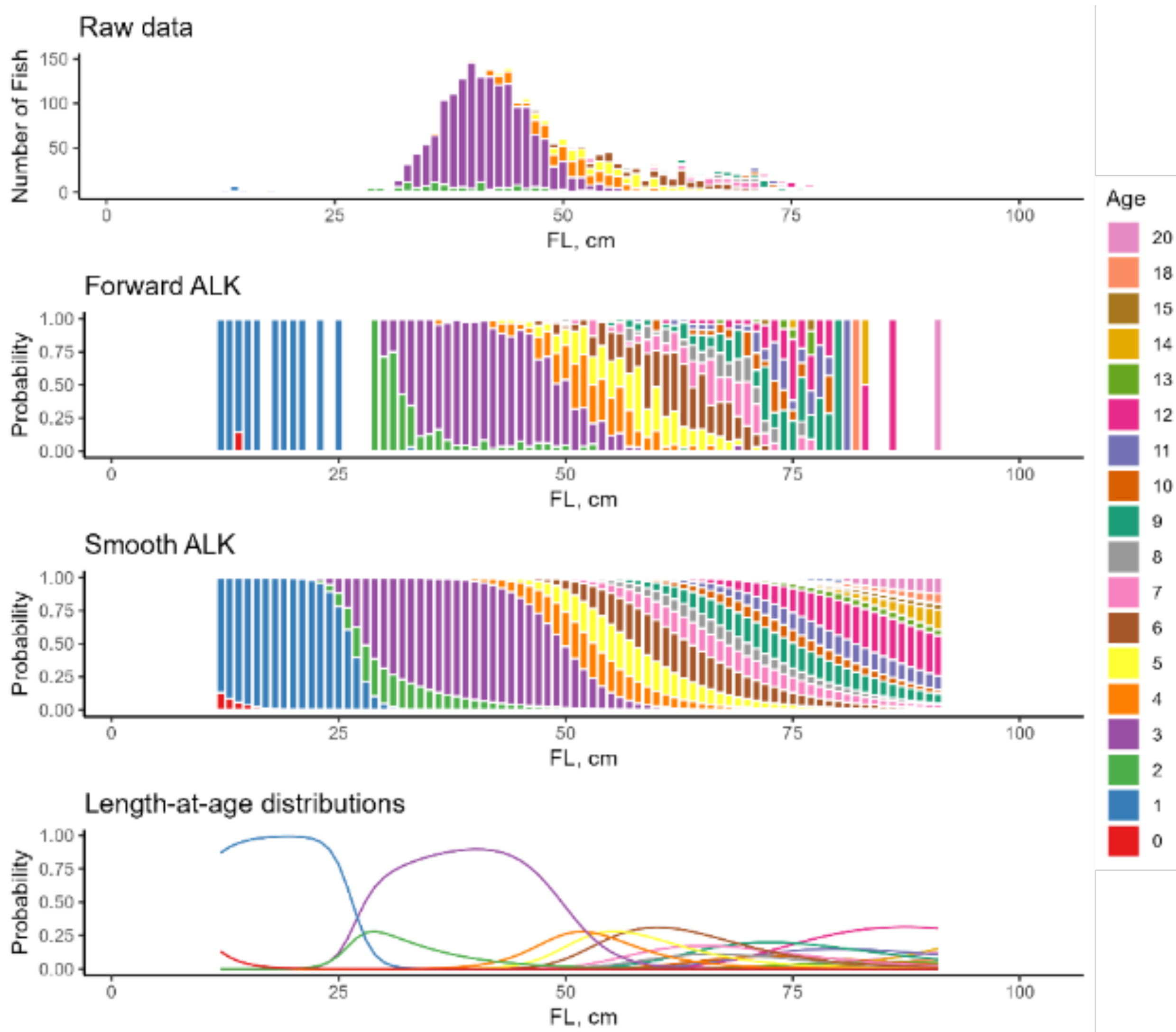

Figure 86. Age data and derived ALKs for 2017 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

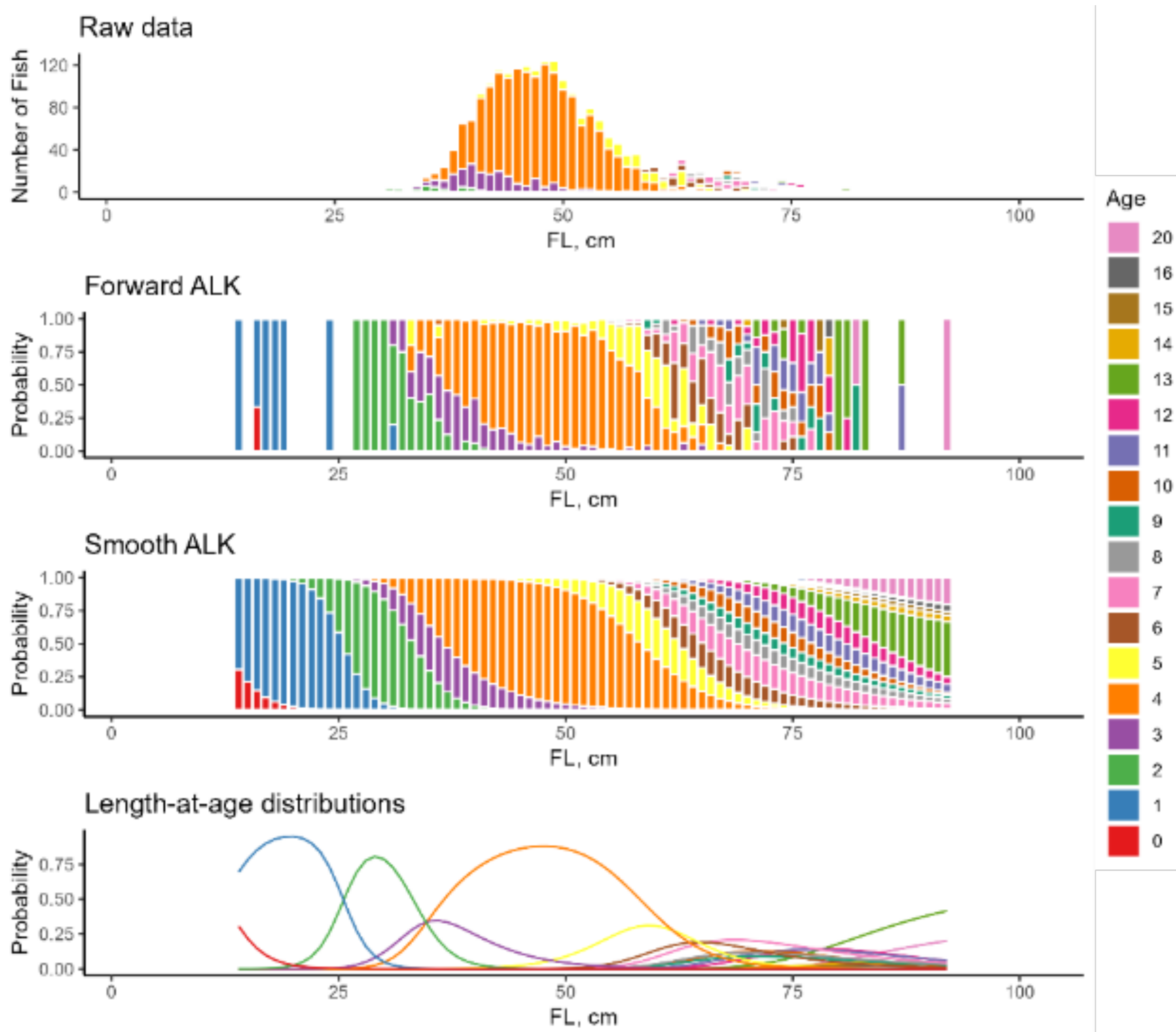

Figure 87. Age data and derived ALKs for 2018 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

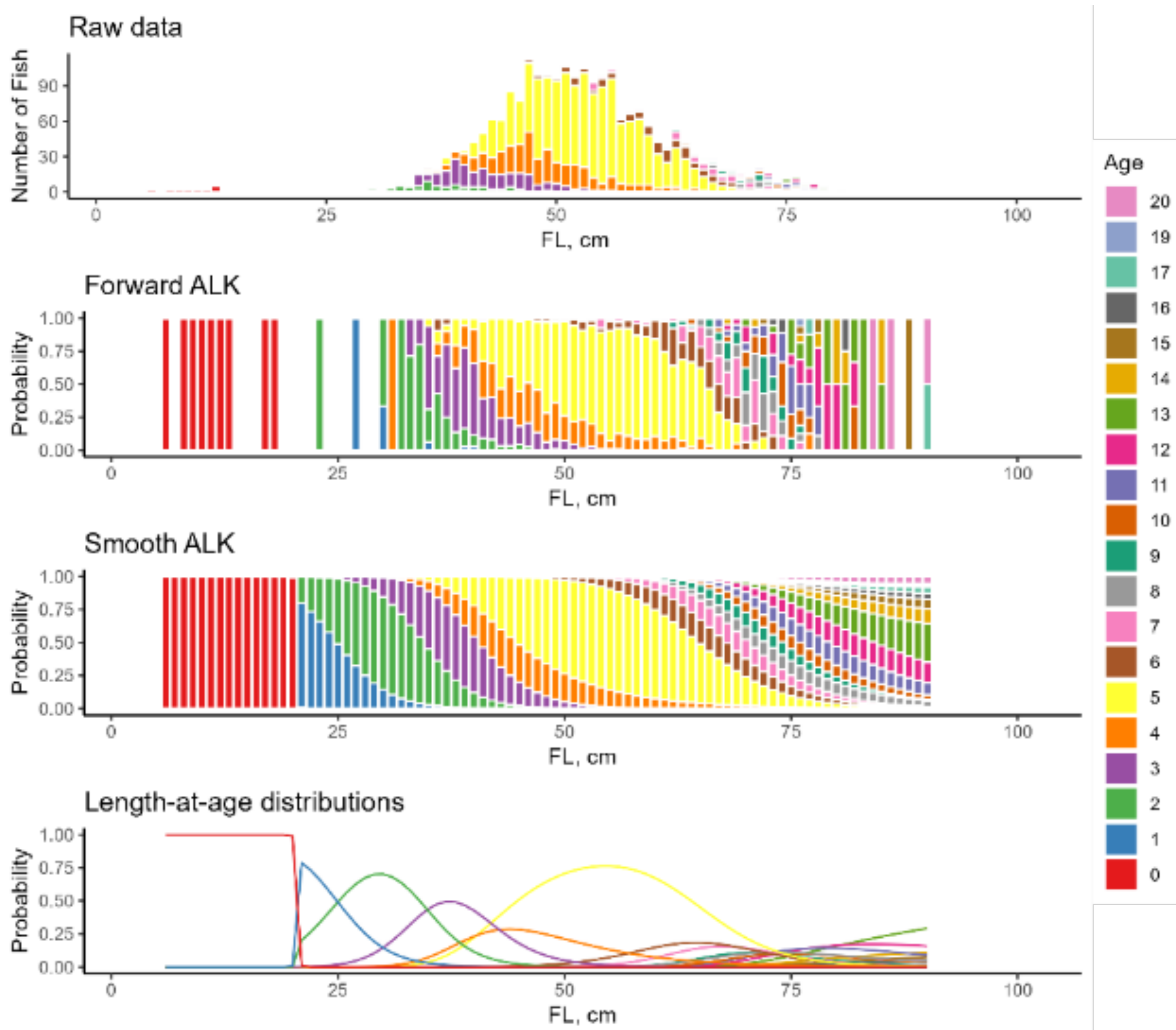

Figure 88. Age data and derived ALKs for 2019 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

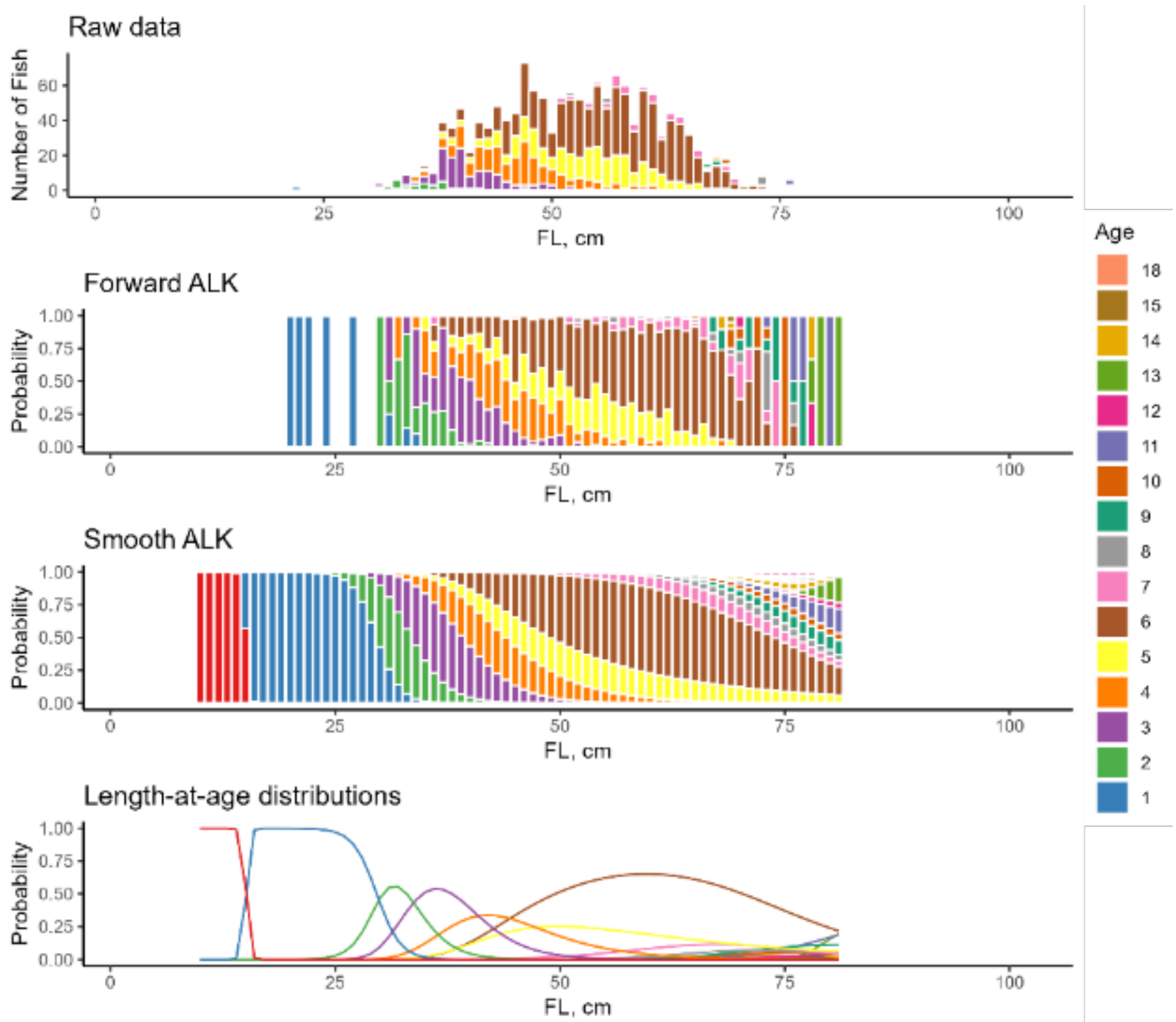

Figure 89. Age data and derived ALKs for 2020 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

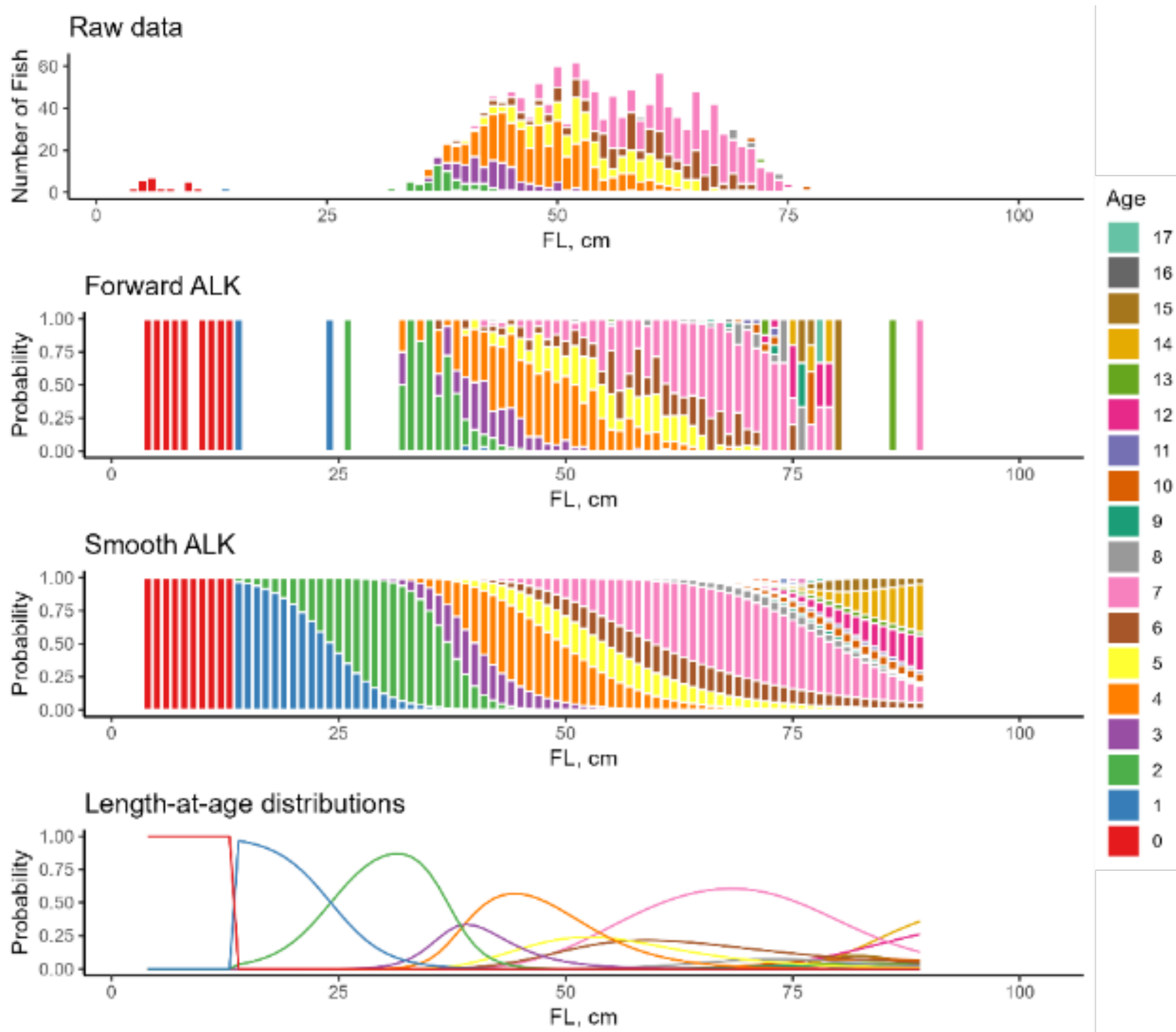

Figure 90. Age data and derived ALKs for 2021 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

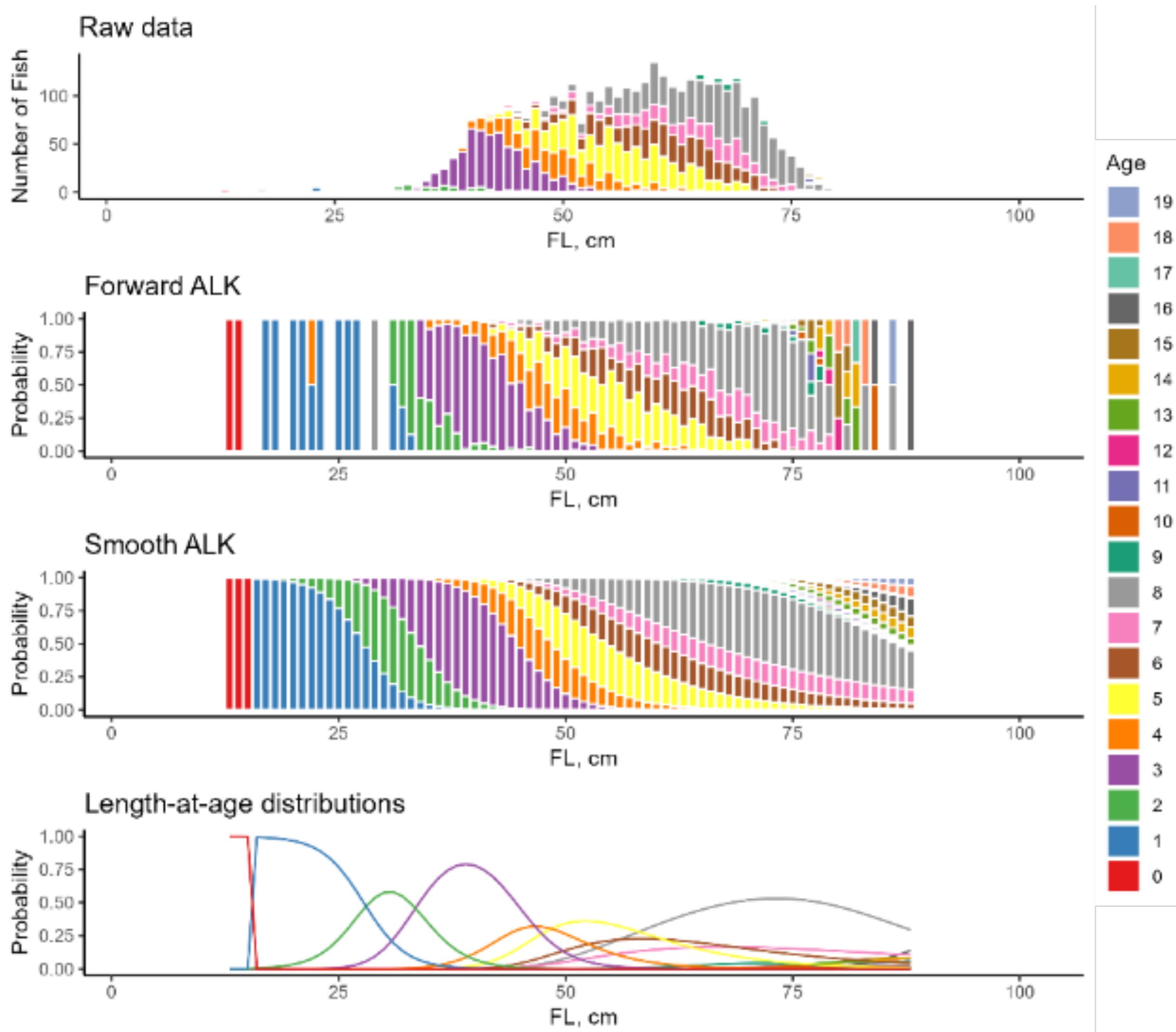

Figure 91. Age data and derived ALKs for 2022 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

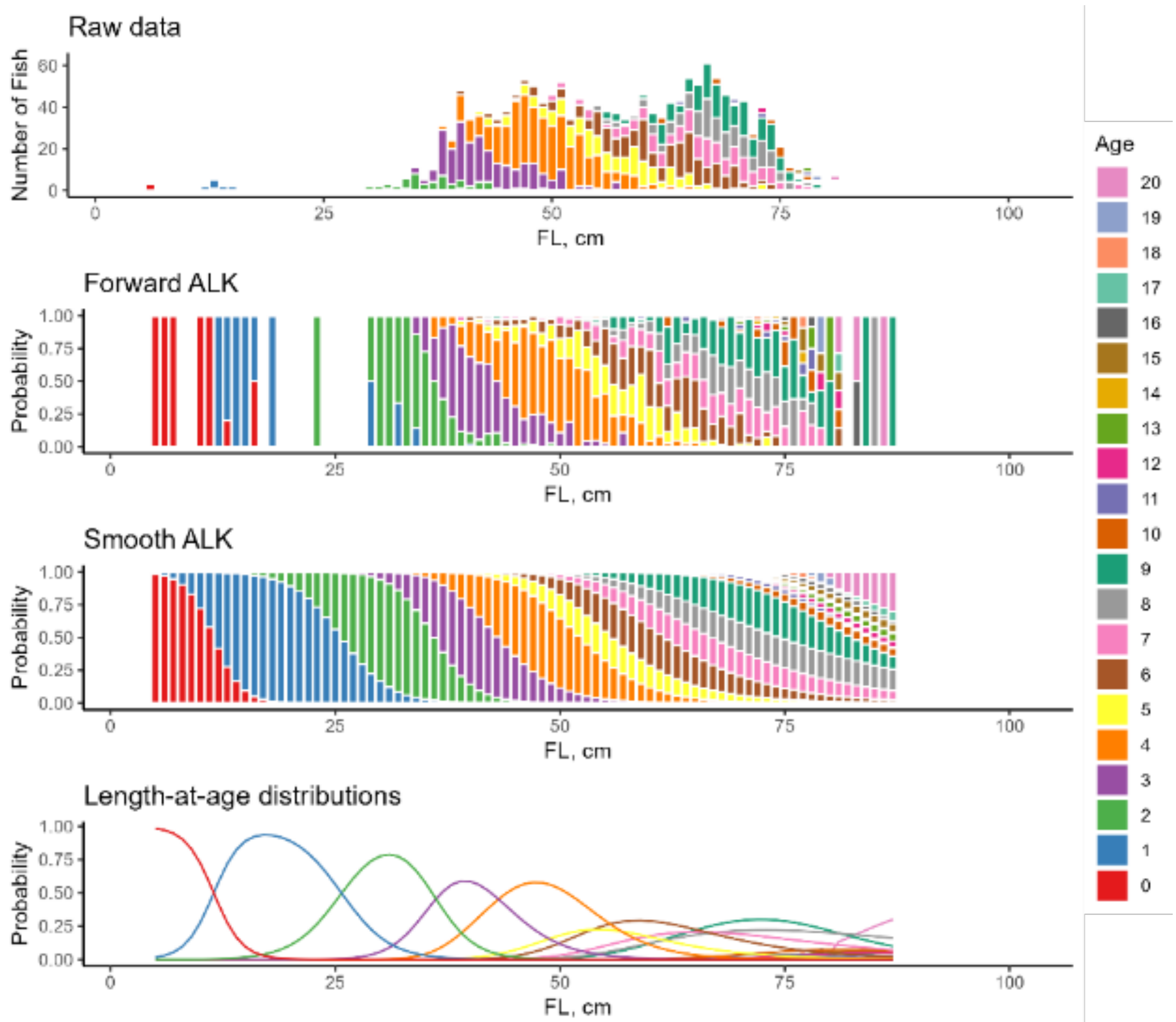

Figure 92. Age data and derived ALKs for 2023 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.