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

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Introduction

Region (West/Central/East) and year (1996-2019) specific smooth age-length keys (Stari et al. 2010) were constructed using Red Snapper samples collected from the Gulf of Mexico from 1996 to 2019. In the last assessment (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 for 1996-2019 are shown in Figure 1. Sample size availability by sector (recreational, commercial, fishery independent) and nominal age distributions are presented in Figure 2, Figure 3 and Figure 4.

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 ($a = 1,2,\ldots,A$) and k to length classes ($k = 1,2,\ldots,K$). 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 $P(k) = \{P(a = 1|k), P(a = 2|k), \ldots P(a = A|k)\}$, where $P(a|k)$ is the probability that a fish in length class k belongs to age class a. The likelihood of observing $\{n_{1k}, n_{2k}, \ldots n_{Ak}\}$ fish for a single length class is proportional to:

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

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 :

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

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

we can then rewrite equation (1) as:

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

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

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

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

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:

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

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 deliniations 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 fish 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. Tables 1-6 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 (Figures 5-7) 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 (Tables 4-6). All three regions suffered from gaps in age 0 fish sampling.

Proportion-at-age bubble plots (Figures 2 - 4) 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. An clear example of that is the strong 2014 year class apparent in the C and E regions (Figures 3 and 4) and the weak 2010 year class apparent in all three regions (Figures 2-4).

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 8 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 and 6). The 10 year plus group minimized gap filling in all regions (Tables 1 - 3).

The development of individual year-region ALKs is shown in Figures 8-80. 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 42 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 45 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 57) 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 lack of age 0 fish sampled is problematic for assigning ages in the smallest length groups. It will therefore be important to compare the age composition estimates resulting from the use of the gap-filled smooth ALK with the age composition estimates resulting from the use of the smooth ALK with no back-filling of age-0 fish. This will help us determine the level of influence that gap-filling has on the results. It will be particularly important to do this exercise for datasets likely to contain high numbers of small Red Snapper like the discard length composition data.

The objective here was to provide an improvement over what was does in the past assessment (i.e. regional ALKs). 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). In the case of Red Snapper, it may be that some of the age-length pairs cannot be assigned to any of the fleets/surveys being modelled in SS. In that case, it will be necessary to input these data as a separate "fake" fleet not associated with any catches or index and a selectivity will need to be assigned.

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Tables

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

year	strat	0	1	2	3	4	5	6	7	8	9	10
1996	**year**	1	1	1	1	1	1	1	1	1	1	1
1997	**all**	1	1	18	6	5	4	1	1	1	1	1
1998	**all**	1	15	177	1,088	721	386	139	77	53	29	139
1999	**all**	1	1	67	506	907	467	219	86	28	10	17
2000	**year**	1	1	68	337	241	201	156	122	66	38	139
2001	**all**	1	1	82	208	314	216	206	112	67	36	121
2002	**all**	1	67	499	2,231	1,059	615	236	193	96	40	227
2003	**all**	1	3	243	1,325	1,473	566	282	152	127	57	254
2004	**all**	1	24	453	1,277	1,244	619	240	164	124	90	356
2005	**all**	1	74	702	1,529	947	639	347	173	111	66	210
2006	**all**	1	2	396	2,126	1,104	403	347	220	103	64	267
2007	**all**	1	10	293	1,310	797	230	171	146	76	48	151
2008	**year**	1	204	132	904	1,144	406	167	99	79	60	120
2009	**year**	1	3	96	907	1,340	960	306	71	48	67	160

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

year	strat	0	1	2	3	4	5	6	7	8	9	10
2010	**all**	1	198	60	536	1,112	980	522	99	21	14	23
2011	**all**	1	4	243	432	1,101	1,422	940	501	126	57	189
2012		7	342	292	1,415	724	1,191	1,105	549	280	72	165
2013		18	279	457	638	2,381	927	828	586	276	130	149
2014	**year**	1	53	181	697	744	1,494	465	451	272	132	145
2015	**year**	1	3	71	513	955	850	751	262	272	175	198
2016	**all**	1	8	100	420	1,232	881	506	323	132	111	291
2017	**year**	1	33	215	625	736	1,502	1,004	537	336	171	553
2018	**year**	1	2	43	408	840	572	1,015	447	263	179	614
2019	**year**	1	1	44	301	763	777	443	461	302	182	839

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

year	strat	0	1	2	3	4	5	6	7	8	9	10
1996	**all**	1	2	65	101	22	8	1	3	1	1	2
1997	**all**	1	1	112	23	14	3	3	1	1	1	1
1998	**all**	1	2	385	1,294	291	71	16	11	6	1	25
1999	**all**	1	1	153	979	995	180	87	40	24	20	23
2000	**all**	1	14	130	968	594	286	101	27	10	5	4
2001	**all**	1	1	324	488	521	265	143	60	19	10	15
2002	**all**	1	6	546	2,274	781	407	147	93	18	5	50
2003	**all**	1	14	1,233	3,571	2,275	443	225	105	41	14	36
2004	**all**	1	14	743	1,962	1,418	624	130	88	42	17	42
2005	**all**	1	46	1,419	3,388	1,062	600	249	54	26	10	31
2006	**all**	1	29	916	2,382	1,041	290	189	113	25	10	27
2007	**all**	1	84	553	1,120	376	75	25	12	8	4	5
2008		3	29	339	749	594	130	28	14	7	6	24
2009		9	42	244	930	676	337	84	22	6	5	4

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

year	strat	0	1	2	3	4	5	6	7	8	9	10
2010	**all**	1	18	191	1,146	1.675	652	366	97	36	13	5
2011	**all**	1	7	235	393	1,799	1,934	843	338	84	25	26
2012		2	68	272	1,058	798	2,046	1,591	613	207	53	61
2013	**year**	1	54	402	518	1,113	589	1,485	1,109	441	163	73
2014		2	27	279	1,382	878	1,237	590	1,301	899	410	206
2015		7	75	410	2,017	1,877	907	897	515	942	652	425
2016	**all**	1	92	1,370	1,239	1,462	751	392	394	241	466	653
2017	**year**	1	138	880	3,067	698	709	310	185	183	110	491
2018	**year**	1	16	1,146	1,847	3,873	590	409	182	99	118	557
2019	**year**	1	72	287	2,713	1,670	2,521	402	257	79	39	314

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

year	strat	0	1	2	3	4	5	6	7	8	9	10
1996	**year**	1	1	1	1	2	3	1	1	1	1	1
1997	**all**	1	1	1	12	18	4	3	1	1	1	1
1998	**year**	1	1	4	6	9	11	6	2	1	1	1
1999	**year**	1	1	1	18	102	31	24	7	1	2	1
2000	**year**	1	1	3	3	23	54	15	6	3	4	3
2001	**all**	1	1	1	19	51	37	35	7	1	1	1
2002	**all**	1	3	12	38	37	29	35	22	5	3	12
2003	**year**	1	1	1	46	71	45	18	17	10	4	9
2004	**year**	1	1	10	76	155	79	18	8	4	1	6
2005	**year**	1	1	7	104	130	142	46	10	1	1	1
2006	**year**	1	1	8	76	186	87	71	21	6	2	9
2007	**year**	1	3	3	46	82	54	22	11	3	1	1
2008		1	5	31	96	101	144	39	10	6	2	1
2009	**year**	1	11	121	476	749	381	194	39	6	1	6

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

year	strat	0	1	2	3	4	5	6	7	8	9	10
2010	**year**	1	1	29	278	820	715	275	136	34	4	5
2011	**year**	1	1	8	126	480	623	320	106	31	12	3
2012	**year**	1	4	17	33	161	343	381	140	40	13	10
2013	**year**	1	1	24	131	185	373	404	308	148	32	24
2014		6	8	35	300	425	295	373	267	264	149	53
2015		8	38	51	185	532	333	167	213	152	114	65
2016	**all**	1	19	404	241	250	403	184	93	101	92	103
2017		1	28	94	1,431	204	181	172	86	47	66	102
2018		1	9	45	199	1,370	165	68	57	31	22	90
2019		19	5	62	184	340	1,194	132	67	30	31	104

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

year	strat	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1996	**all**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1997	**all**	1	1	18	6	5	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1998	**all**	1	15	177	1,08	721	386	139	77	53	29	28	19	16	15	9	10	9	5	4	1	23
1999	**year**	1	1	67	506	907	467	219	86	28	10	7	2	1	1	1	1	1	1	1	1	7
2000	**year**	1	1	68	337	241	201	156	122	66	38	24	17	17	10	7	10	6	4	2	2	40
2001	**all**	1	1	82	208	314	216	206	112	67	36	19	18	15	12	8	5	11	2	2	3	26
2002	**all**	1	67	499	2,23	1,05	615	236	193	96	40	32	36	23	12	25	12	15	11	8	4	49
2003	**all**	1	3	243	1,32	1,47	566	282	152	127	57	44	32	34	23	22	18	20	8	7	3	43
2004	**all**	1	24	453	1,27	1,24	619	240	164	124	90	63	42	49	39	34	27	21	9	11	7	54
2005	**all**	1	74	702	1,52	947	639	347	173	111	66	43	27	30	32	22	16	8	4	11	3	14
2006	**all**	1	2	396	2,12	1,10	403	347	220	103	64	70	40	33	25	19	20	10	9	4	5	32
2007	**all**	1	10	293	1,31	797	230	171	146	76	48	32	34	11	14	9	16	9	3	5	3	15
2008	**year**	1	204	132	904	1,14	406	167	99	79	60	36	22	19	4	5	5	6	3	2	2	16
2009	**year**	1	3	96	907	1,34	960	306	71	48	67	40	24	14	12	14	9	8	3	3	4	29

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

year	strat	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2010	**all**	1	198	60	536	1.11	980	522	99	21	14	5	1	2	1	3	1	2	1	1	1	8
2011	**all**	1	4	243	432	1,10	1,42	940	501	126	57	27	32	13	15	6	10	4	8	8	7	59
2012		7	342	292	1,41	724	1,19	1,10	549	280	72	40	15	14	14	9	6	9	10	10	6	32
2013		18	279	457	638	2,38	927	828	586	276	130	38	13	10	17	12	13	6	3	2	8	27
2014	**year**	1	53	181	697	744	1,49	465	451	272	132	70	24	11	4	8	8	5	6	2	2	5
2015	**year**	1	3	71	513	955	850	751	262	272	175	84	42	13	5	6	5	3	5	5	2	28
2016	**year**	1	8	100	420	1,23	881	506	323	132	111	104	65	51	19	9	8	6	8	8	1	13
2017	**year**	1	33	215	625	736	1,50	1,00	537	336	171	160	147	92	47	22	23	9	8	4	5	36
2018	**year**	1	2	43	408	840	572	1,01	447	263	179	158	141	142	68	44	13	8	3	9	4	24
2019	**year**	1	1	44	301	763	777	443	461	302	182	148	141	140	111	102	64	40	21	12	8	52

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

year	strat	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1996	**all**	1	2	65	101	22	8	1	3	1	1	2	1	1	1	1	1	1	1	1	1	1
1997	**all**	1	1	112	23	14	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1998	**year**	1	2	385	1,29	291	71	16	11	6	1	1	2	2	1	1	1	3	2	1	1	14
1999	**all**	1	1	153	979	995	180	87	40	24	20	12	5	1	2	1	1	1	1	1	1	3
2000	**year**	1	14	130	968	594	286	101	27	10	5	1	3	1	1	1	1	1	1	1	1	1
2001	**year**	1	1	324	488	521	265	143	60	19	10	5	5	1	1	1	1	1	1	1	1	3
2002	**year**	1	6	546	2,27	781	407	147	93	18	5	6	5	10	9	1	1	1	1	1	2	16
2003	**year**	1	14	1,23	3,57	2,27	443	225	105	41	14	3	4	4	1	3	1	2	2	2	1	14
2004	**year**	1	14	743	1,96	1,41	624	130	88	42	17	5	7	9	5	1	5	1	1	1	1	10
2005	**year**	1	46	1,41	3,38	1,06	600	249	54	26	10	12	4	1	3	7	1	1	1	1	1	3
2006	**year**	1	29	916	2,38	1,04	290	189	113	25	10	6	3	3	3	2	2	2	1	1	2	3
2007	**year**	1	84	553	1,12	376	75	25	12	8	4	2	1	1	1	1	1	1	1	1	1	1
2008	**year**	3	29	339	749	594	130	28	14	7	6	5	3	3	1	3	2	2	1	1	1	4
2009	**year**	9	42	244	930	676	337	84	22	6	5	1	1	1	1	1	1	1	1	1	1	1

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

year	strat	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2010	**year**	1	18	191	1.14	1.67	652	366	97	36	13	3	1	1	1	1	1	1	1	1	1	1
2011	**year**	1	7	235	393	1,79	1,93	843	338	84	25	7	4	3	1	2	1	2	1	1	1	6
2012	**year**	2	68	272	1,05	798	2,04	1,59	613	207	53	19	10	2	8	1	3	3	5	3	2	6
2013	**year**	1	54	402	518	1,11	589	1,48	1,10	441	163	34	16	6	5	2	1	1	3	4	1	2
2014		2	27	279	1,38	878	1,23	590	1,30	899	410	122	26	14	10	10	5	1	3	4	1	10
2015		7	75	410	2,01	1,87	907	897	515	942	652	289	79	24	10	5	2	4	2	2	2	6
2016	**year**	1	92	1,37	1,23	1,46	751	392	394	241	466	353	180	71	15	10	5	6	1	1	1	11
2017	**year**	1	138	880	3,06	698	709	310	185	183	110	170	156	95	40	11	3	6	1	1	1	7
2018	**year**	1	16	1,14	1,84	3,87	590	409	182	99	118	74	146	153	85	45	25	11	3	4	6	5
2019	**year**	1	72	287	2,71	1,67	2,52	402	257	79	39	58	31	68	49	52	21	8	7	3	4	13

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

year	strat	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1996	**all**	1	1	1	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1997	**all**	1	1	1	12	18	4	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1998	**year**	1	1	4	6	9	11	6	2	1	1	1	1	1	1	1	1	1	1	1	1	1
1999	**year**	1	1	1	18	102	31	24	7	1	2	1	1	1	1	1	1	1	1	1	1	1
2000	**year**	1	1	3	3	23	54	15	6	3	4	1	1	1	1	1	1	1	1	1	1	1
2001	**year**	1	1	1	19	51	37	35	7	1	1	1	1	1	1	1	1	1	1	1	1	1
2002	**year**	1	3	12	38	37	29	35	22	5	3	2	1	1	1	1	1	1	1	1	1	8
2003	**year**	1	1	1	46	71	45	18	17	10	4	1	1	1	1	1	1	1	1	1	1	4
2004	**year**	1	1	10	76	155	79	18	8	4	1	2	1	1	1	1	1	1	1	1	1	2
2005	**year**	1	1	7	104	130	142	46	10	1	1	1	1	1	1	1	1	1	1	1	1	1
2006	**year**	1	1	8	76	186	87	71	21	6	2	1	1	1	2	1	1	1	1	1	1	2
2007	**year**	1	3	3	46	82	54	22	11	3	1	1	1	1	1	1	1	1	1	1	1	1
2008	**year**	1	5	31	96	101	144	39	10	6	2	1	1	1	1	1	1	1	1	1	1	1
2009	**year**	1	11	121	476	749	381	194	39	6	1	1	1	1	1	1	1	1	1	1	1	2

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

year	strat	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2010	**all**	1	1	29	278	820	715	275	136	34	4	3	1	1	1	1	1	1	1	1	1	1
2011	**year**	1	1	8	126	480	623	320	106	31	12	2	1	1	1	1	1	1	1	1	1	1
2012	**year**	1	4	17	33	161	343	381	140	40	13	6	2	1	1	1	1	1	1	1	1	1
2013	**year**	1	1	24	131	185	373	404	308	148	32	8	6	3	3	2	1	1	1	1	1	1
2014	**year**	6	8	35	300	425	295	373	267	264	149	42	8	1	2	1	1	1	1	1	1	1
2015	**year**	8	38	51	185	532	333	167	213	152	114	53	6	1	3	1	1	1	1	1	1	2
2016	**year**	1	19	404	241	250	403	184	93	101	92	59	27	3	5	4	3	1	1	1	1	1
2017	**year**	1	28	94	1,43	204	181	172	86	47	66	29	27	35	5	2	2	1	1	1	1	1
2018	**year**	1	9	45	199	1,37	165	68	57	31	22	27	22	20	13	3	2	1	1	1	1	2
2019	**year**	19	5	62	184	340	1,19	132	67	30	31	22	24	21	17	7	4	3	2	1	1	4

Figures

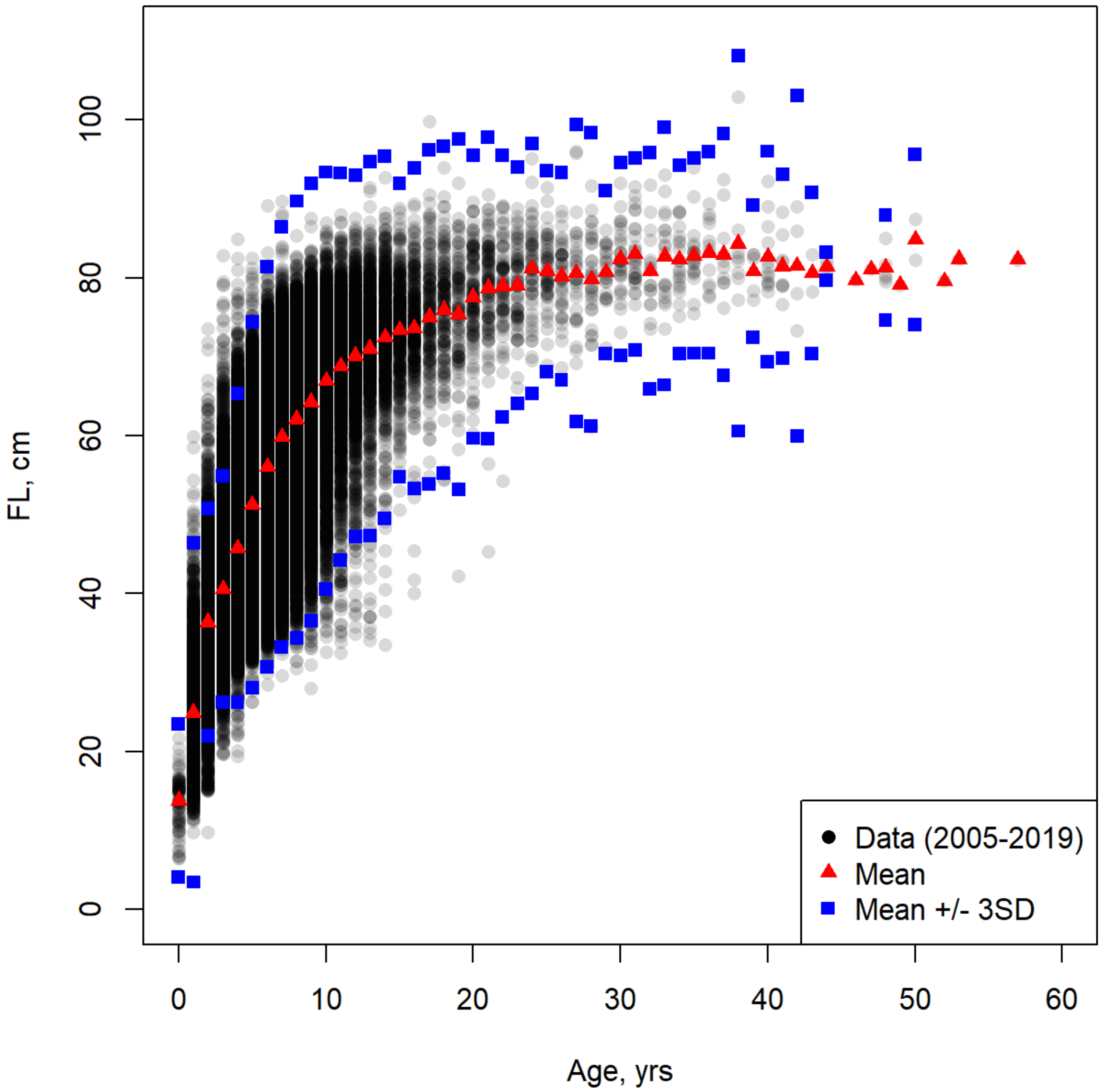

Figure 1: Age-length pairs available for 2005-2019, all sources combined. Mean length-at-age and 3 standard deviations about the mean are shown. Data points that fall well beyond the 3 standard deviation limits are likely a result of ageing error.

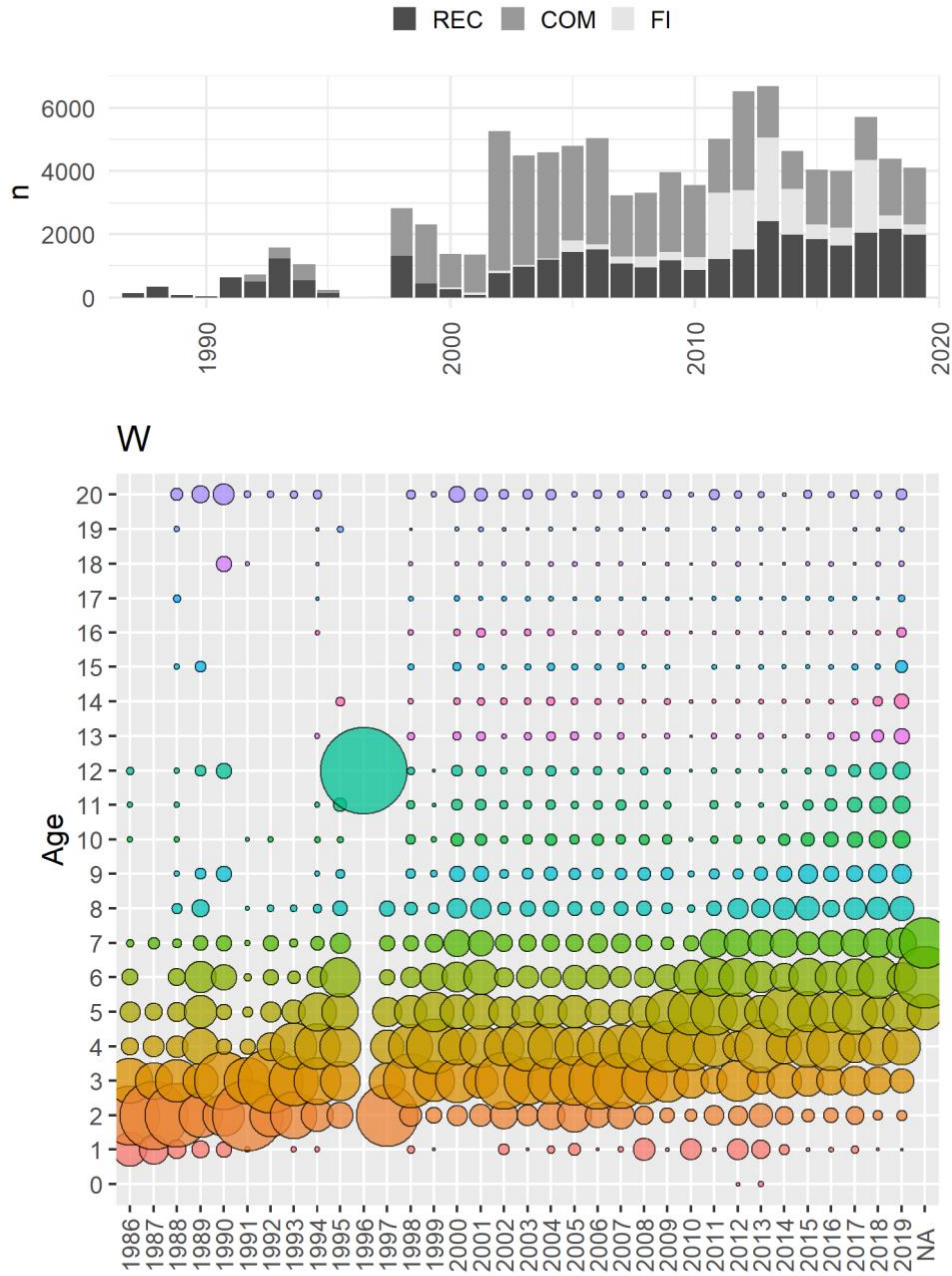

Figure 2: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico Red Snapper for all sectors combined in the Western region and associated sample sizes by sector (upper histogram). Cohort progressions are most evident in recent years.

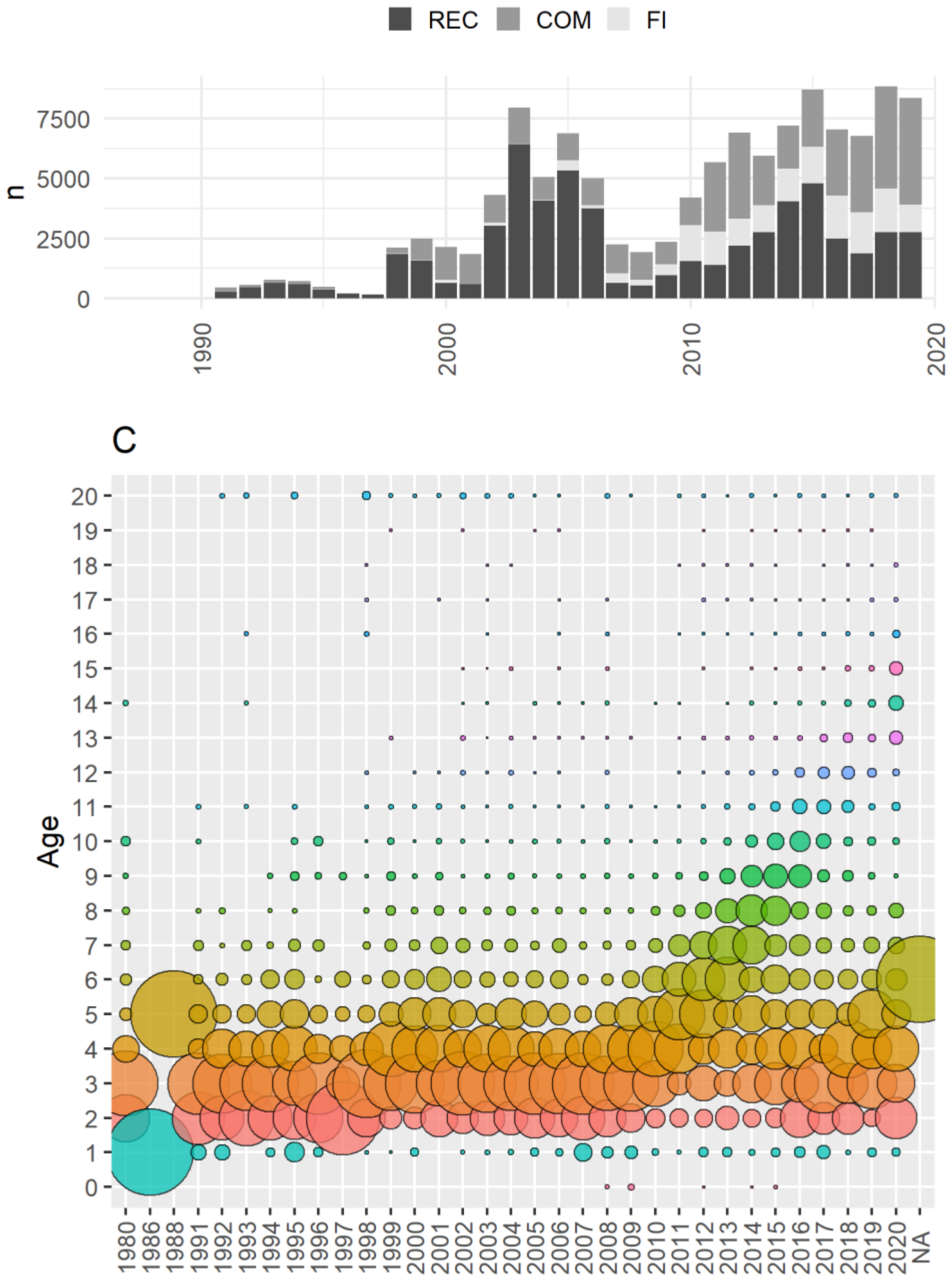

Figure 3: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico Red Snapper for all sectors combined in the Central region and associated sample sizes by sector (upper histogram). Cohort progressions are most evident in recent years.

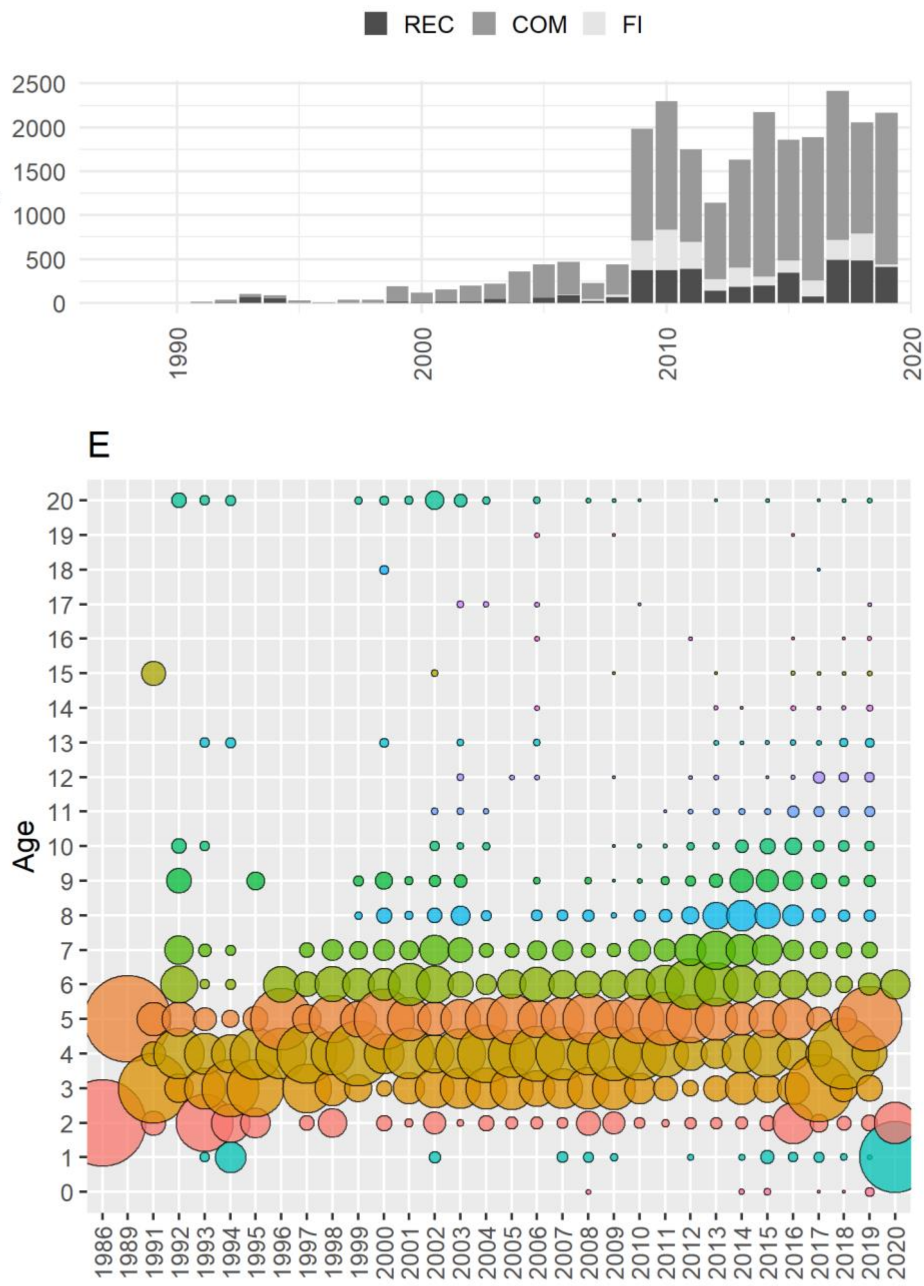

Figure 4: Nominal age composition (bubble plot) shown as relative age proportions observed in each year for Gulf of Mexico Red Snapper for all sectors combined in the Eastern region and associated sample sizes by sector (upper histogram). Cohort progressions are most evident in recent years.

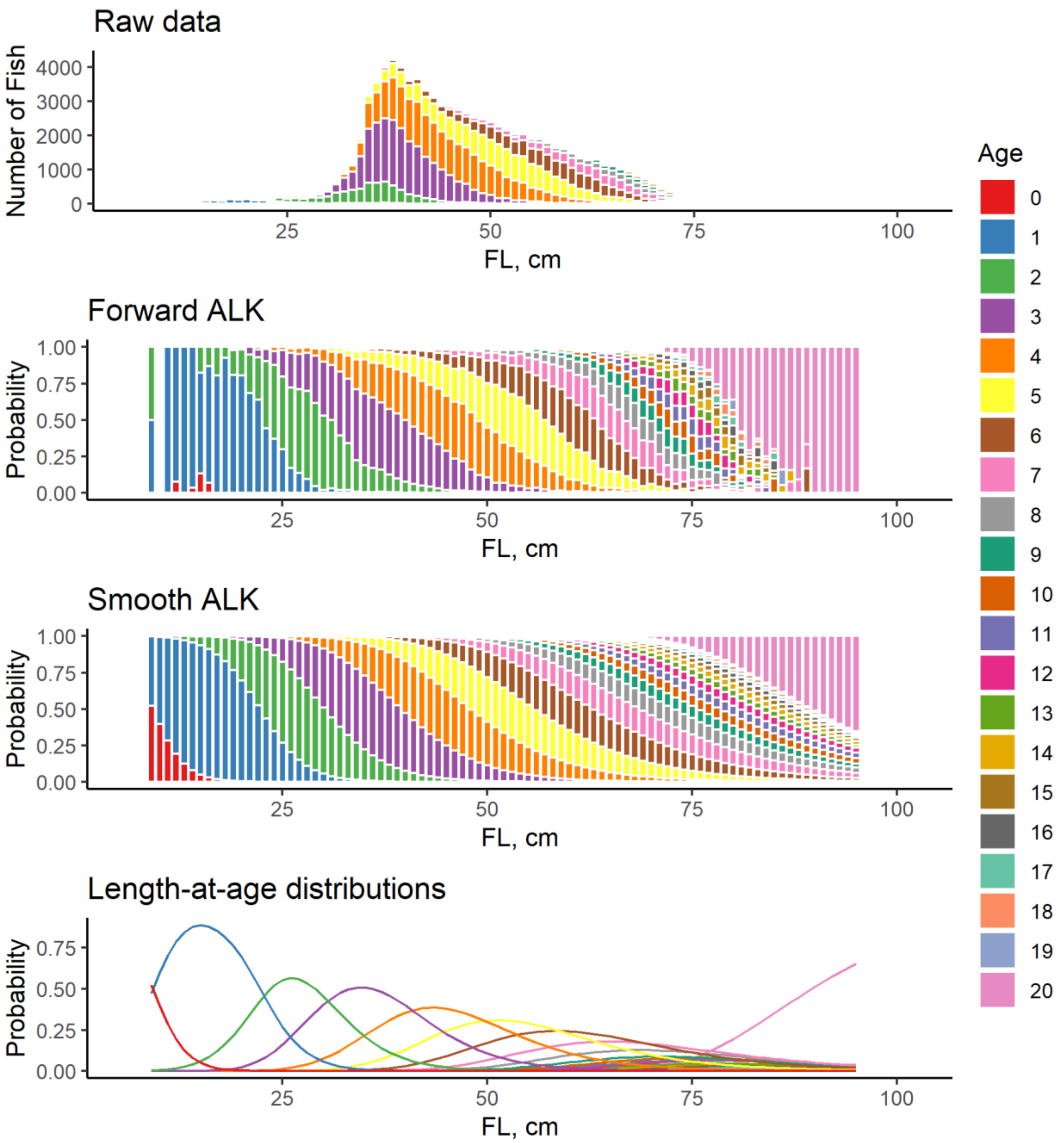

Figure 5: Age data and derived ALKs (pooled years) for the Western region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

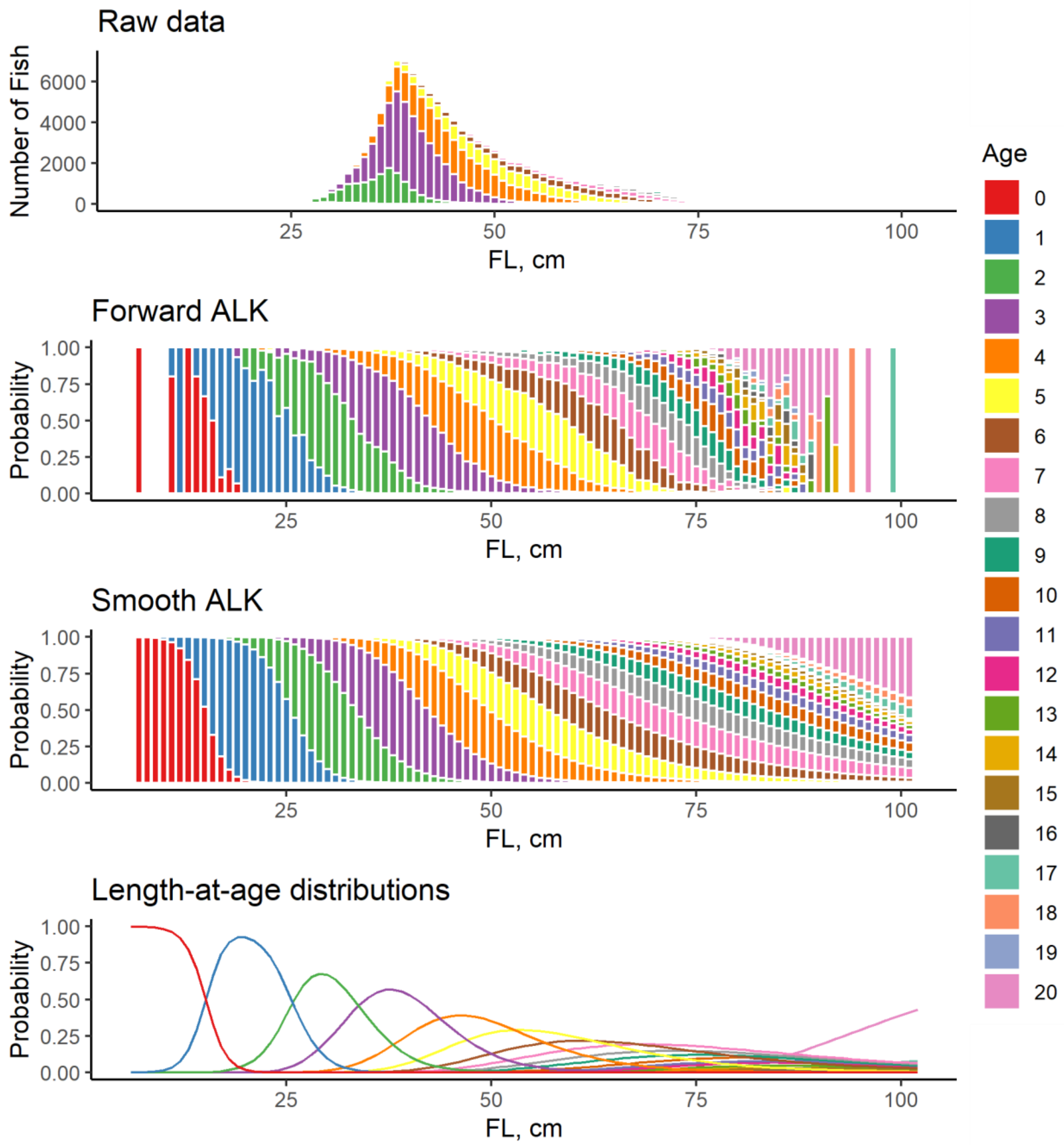

Figure 6: Age data and derived ALKs (pooled years) for the Central region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

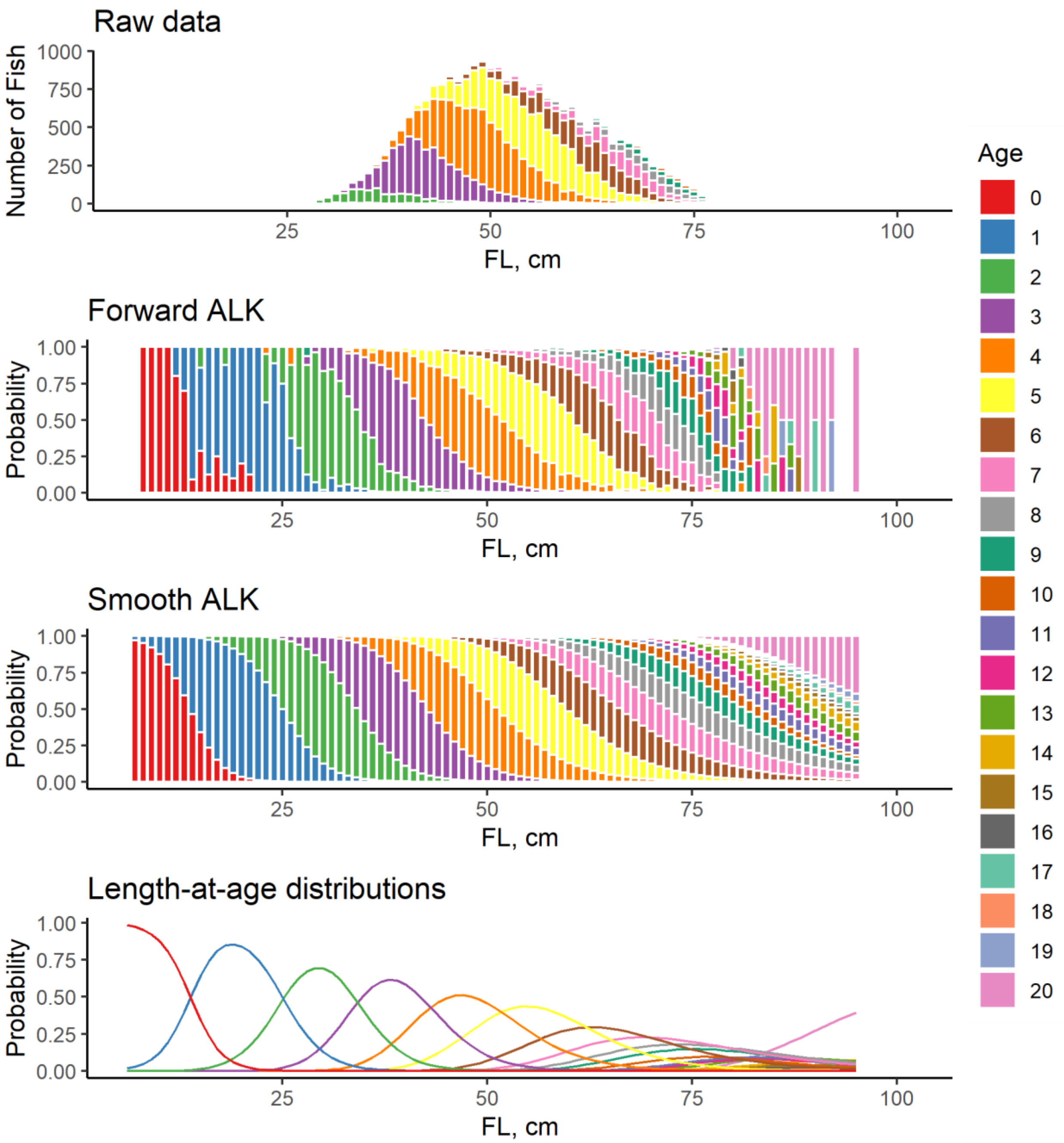

Figure 7: Age data and derived ALKs (pooled years) for the Eastern region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

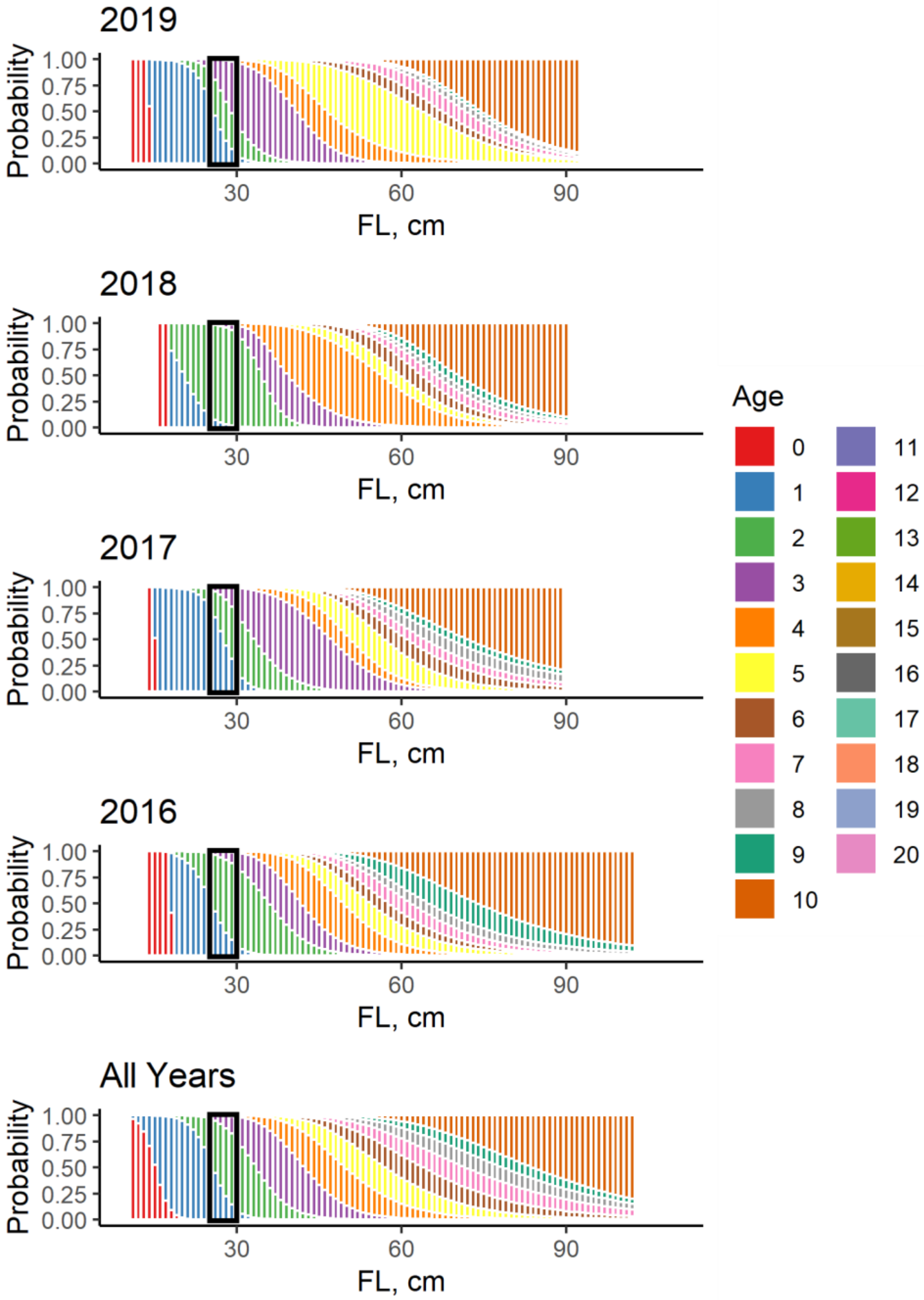

Figure 8: Year-specific ALKs (2016-2019) vs. pooled ALK (All Years) for the Central region. There are clear signals of strong 2014 and 2016 cohorts moving through the population in the year-specific ALKs. The black rectangles show how different the age composition within the 25-30cm length bin is from 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.

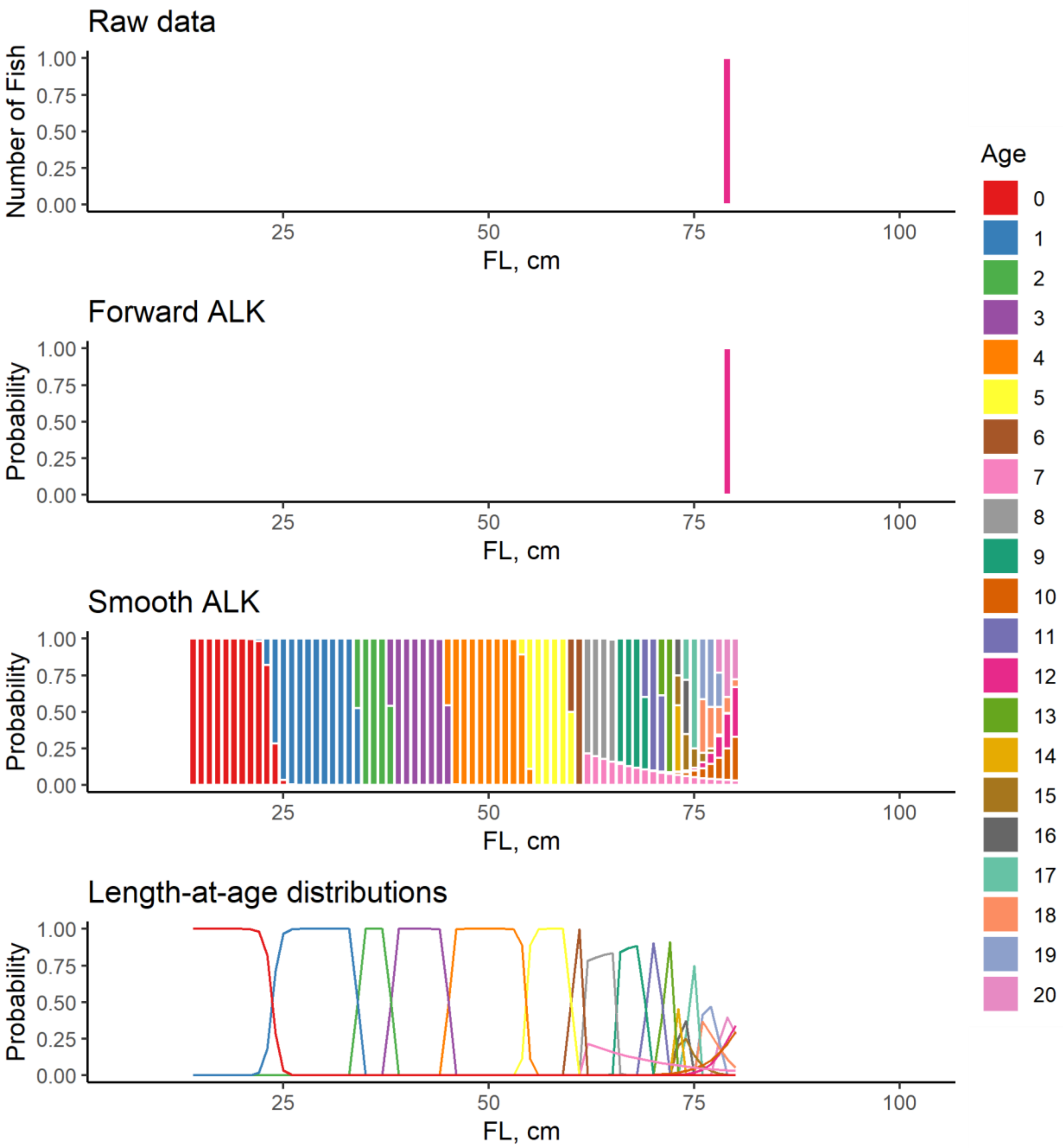

Figure 9. Age data and derived ALKs for 1996 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

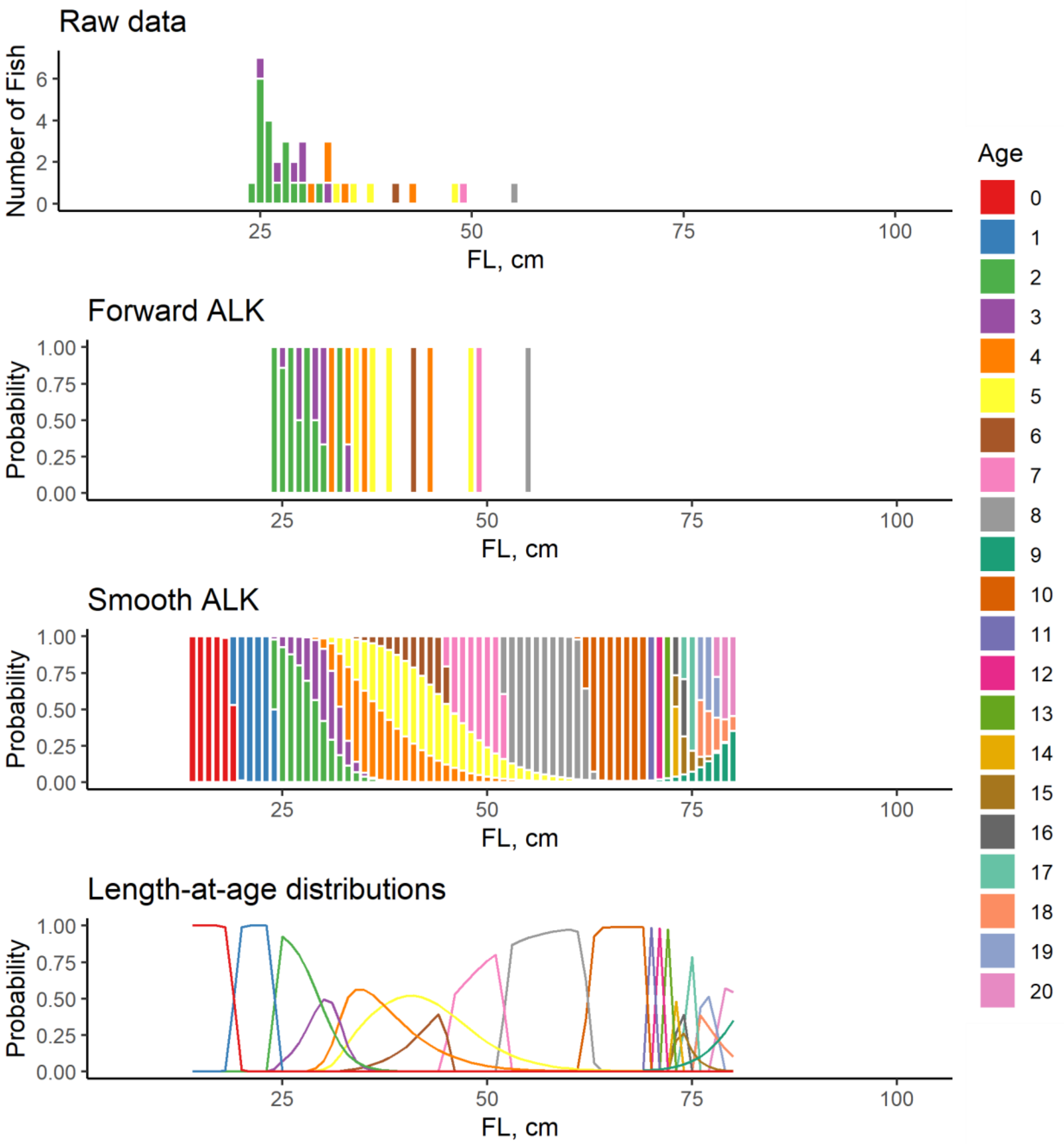

Figure 10. Age data and derived ALKs for 1997 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

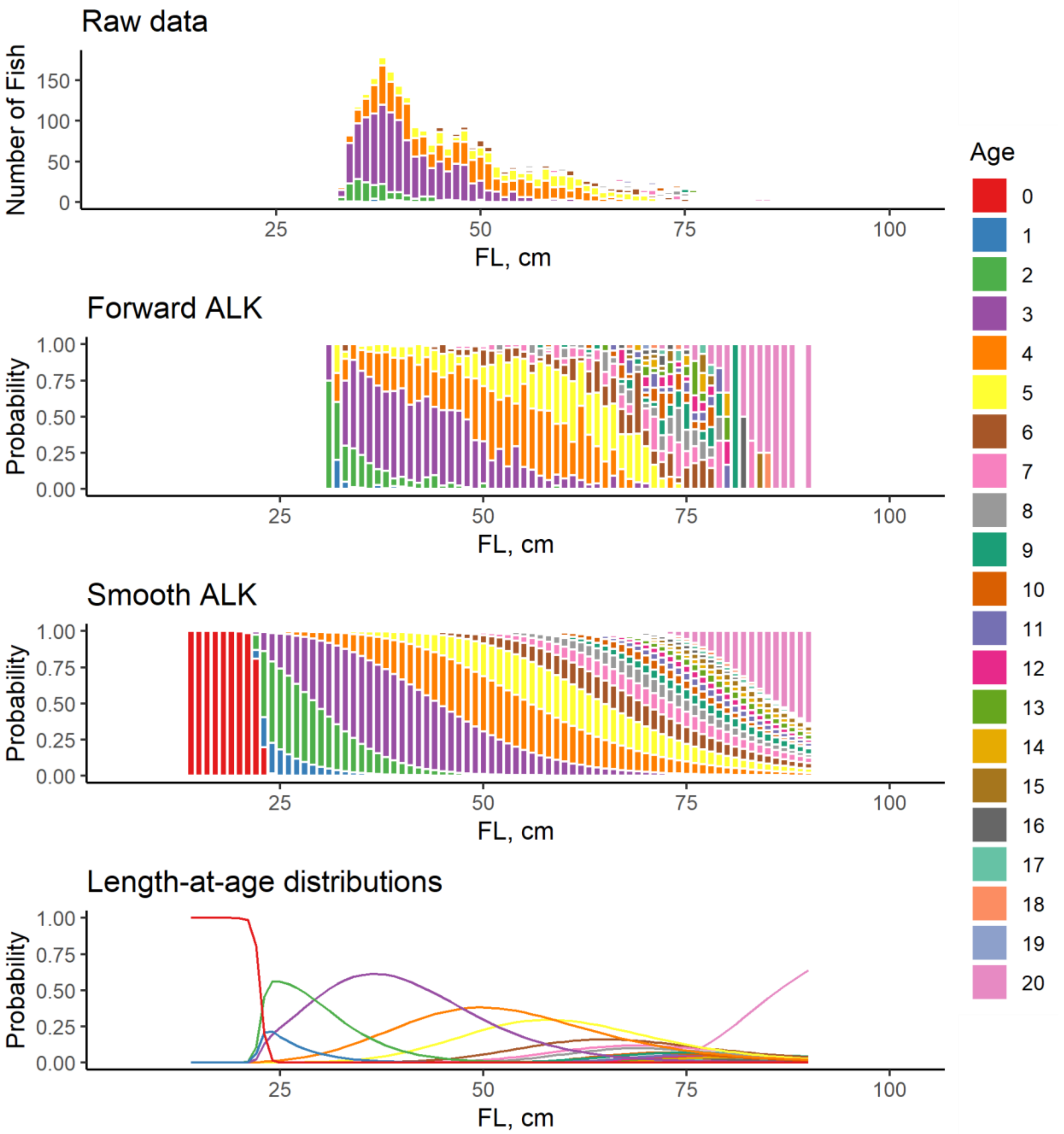

Figure 11. Age data and derived ALKs for 1998 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

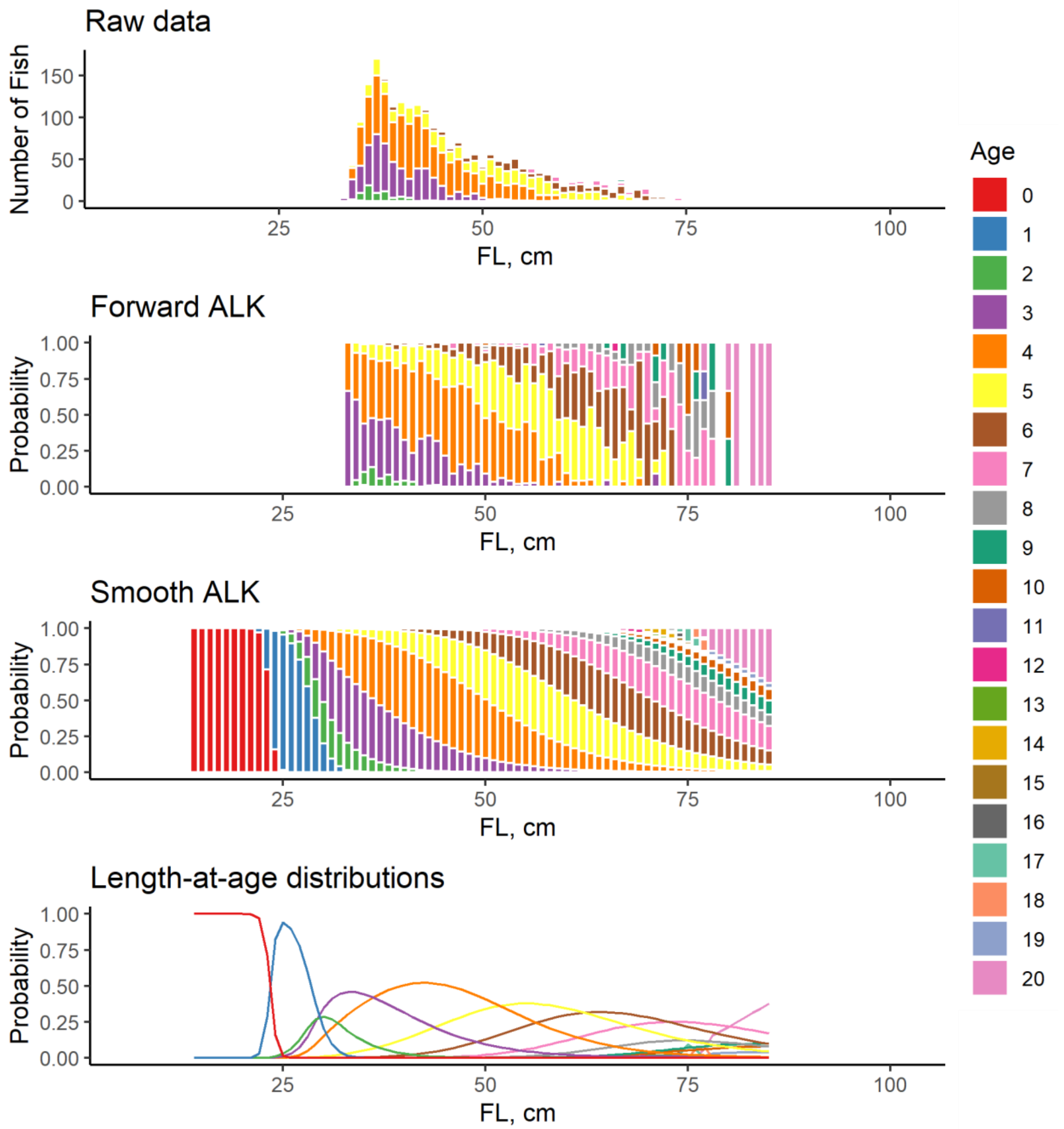

Figure 12. Age data and derived ALKs for 1999 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

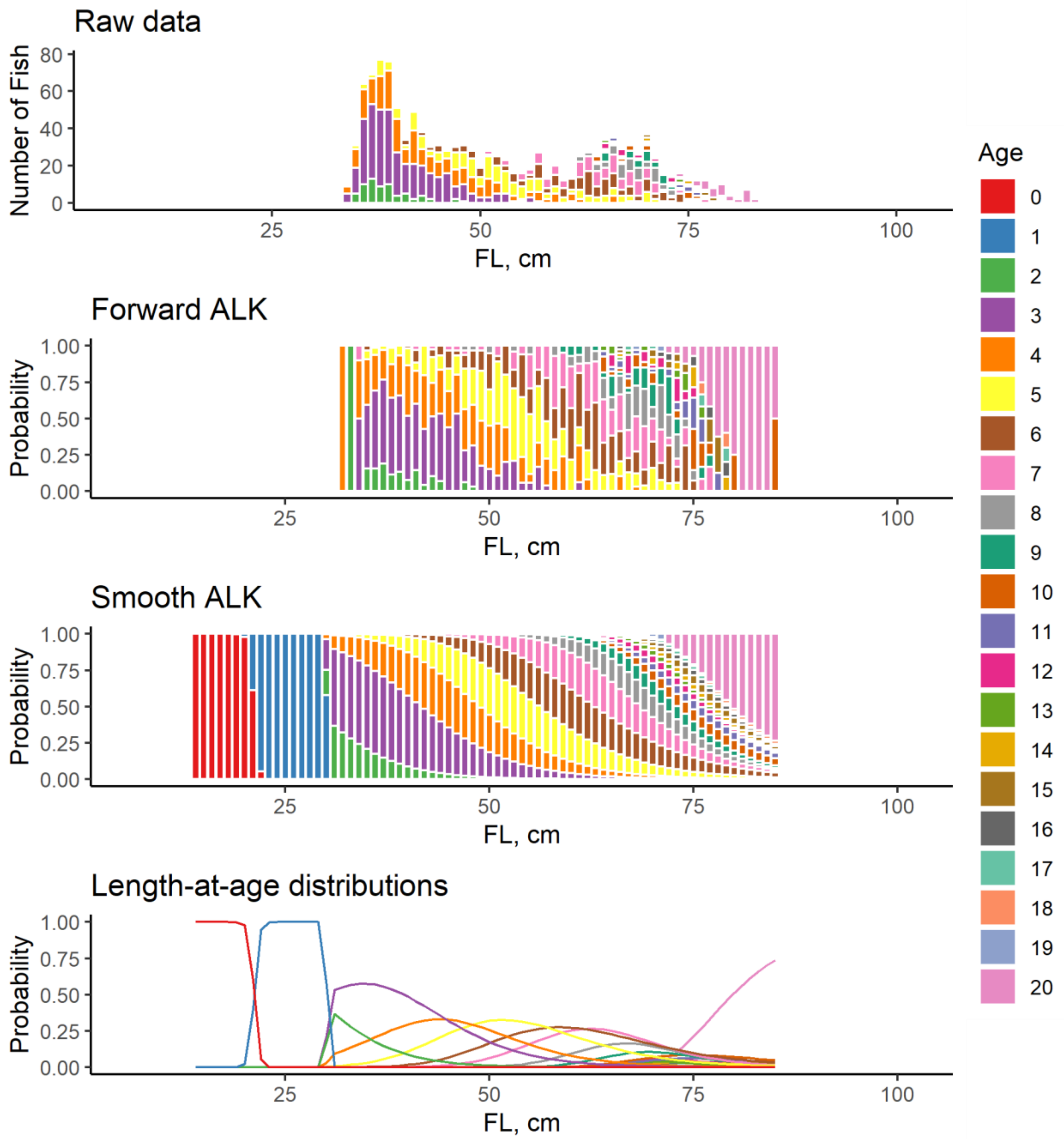

Figure 13. Age data and derived ALKs for 2000 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

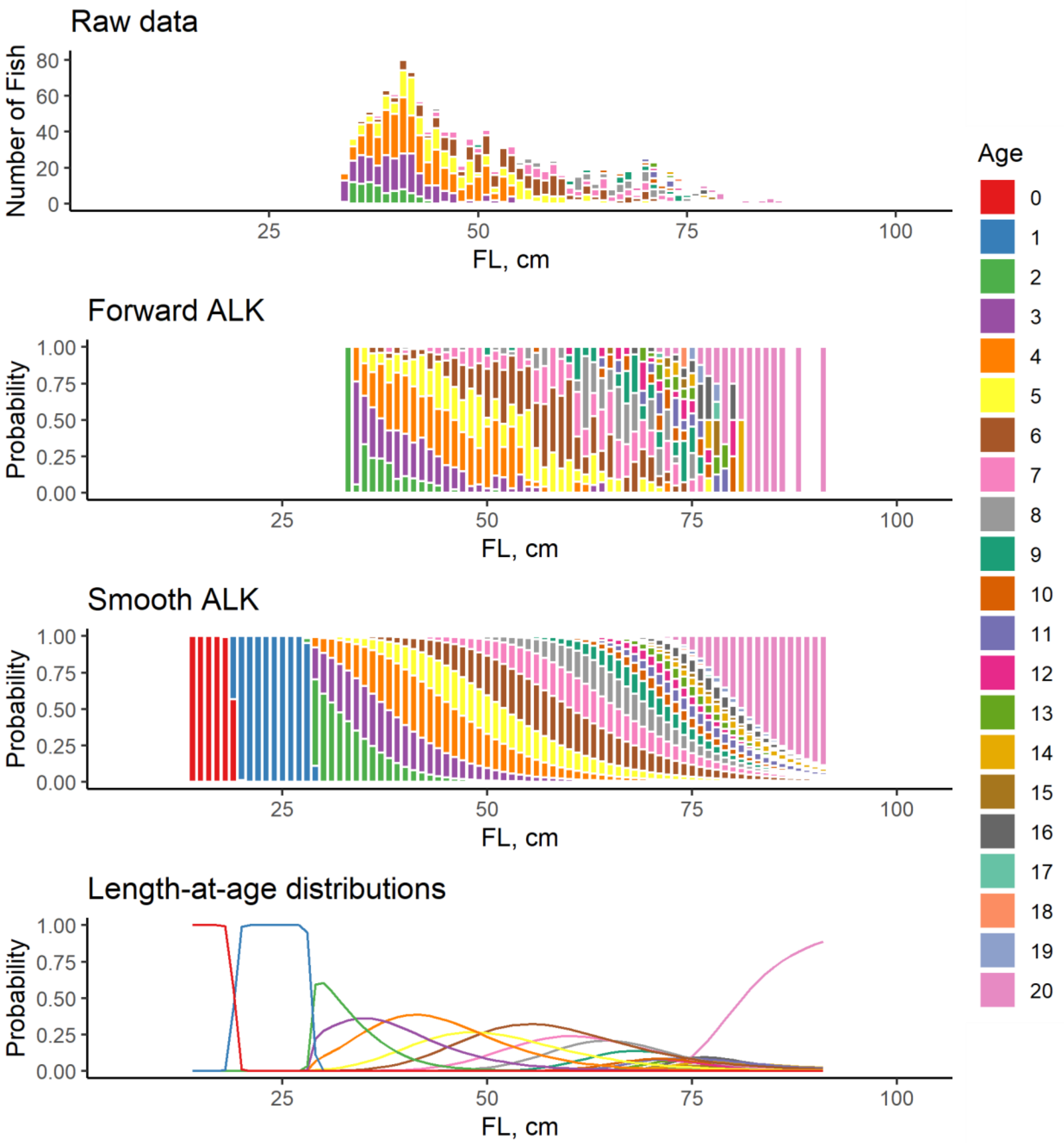

Figure 14. Age data and derived ALKs for 2001 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

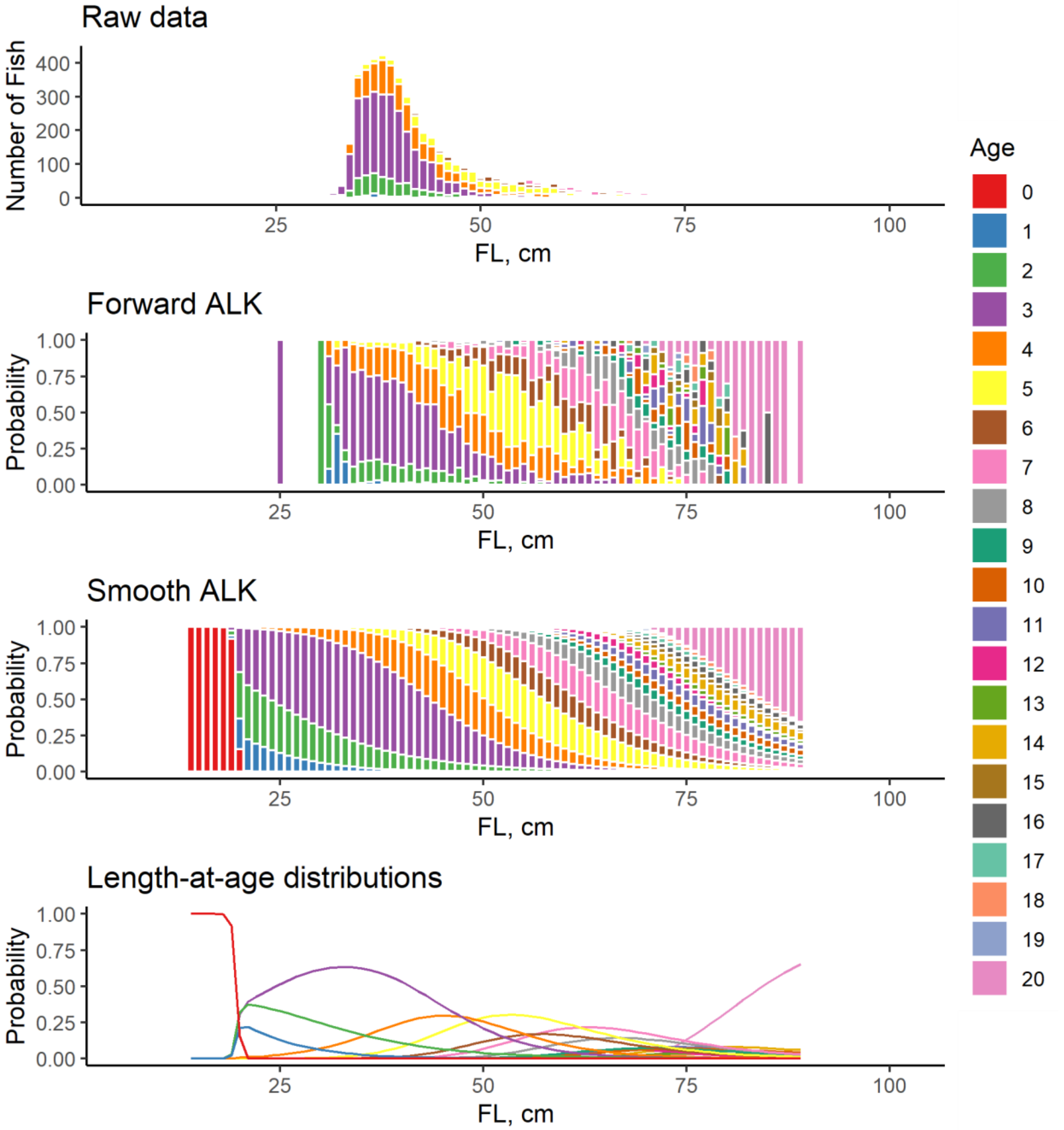

Figure 15. Age data and derived ALKs for 2002 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

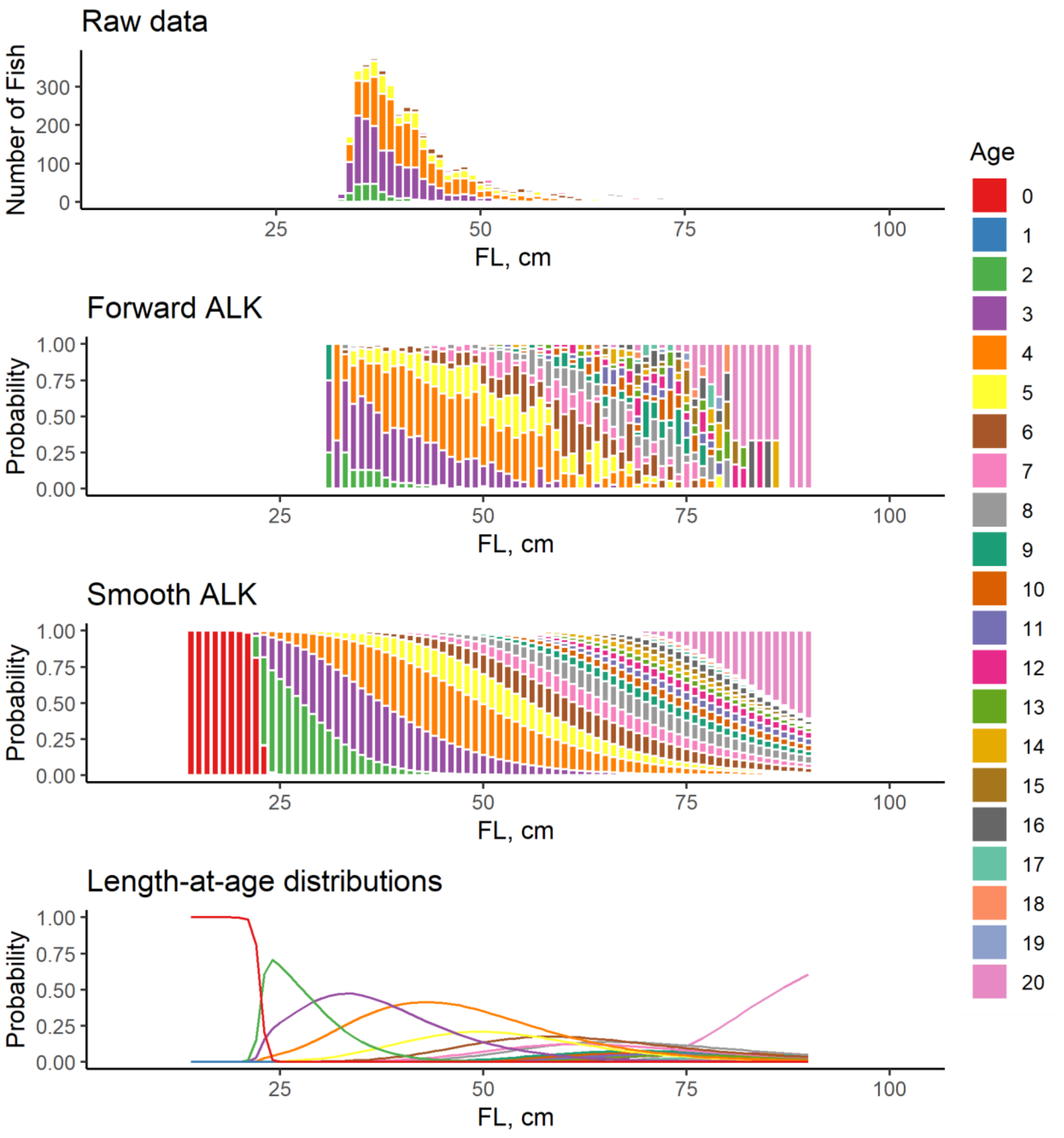

Figure 16. Age data and derived ALKs for 2003 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

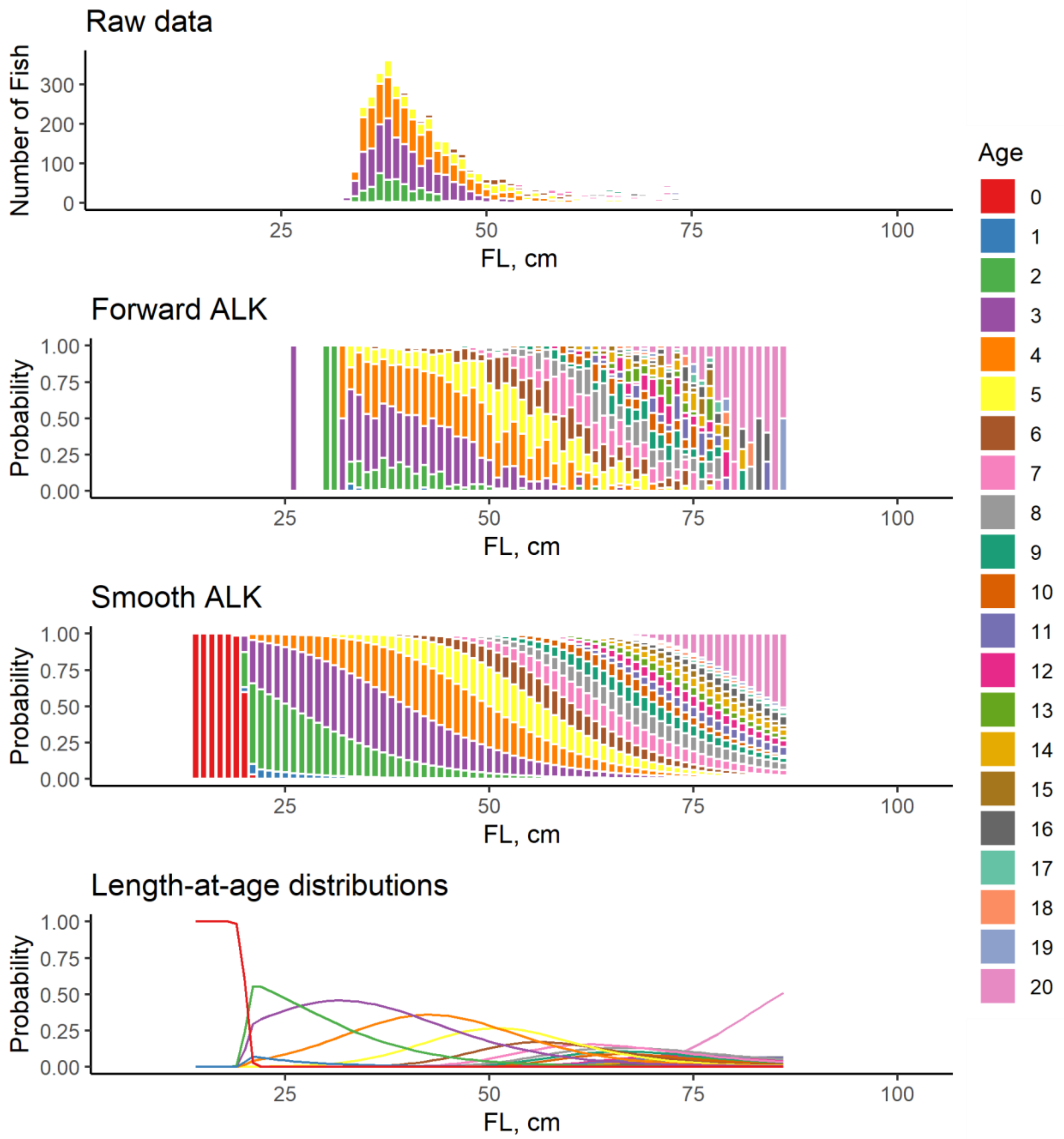

Figure 17. Age data and derived ALKs for 2004 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

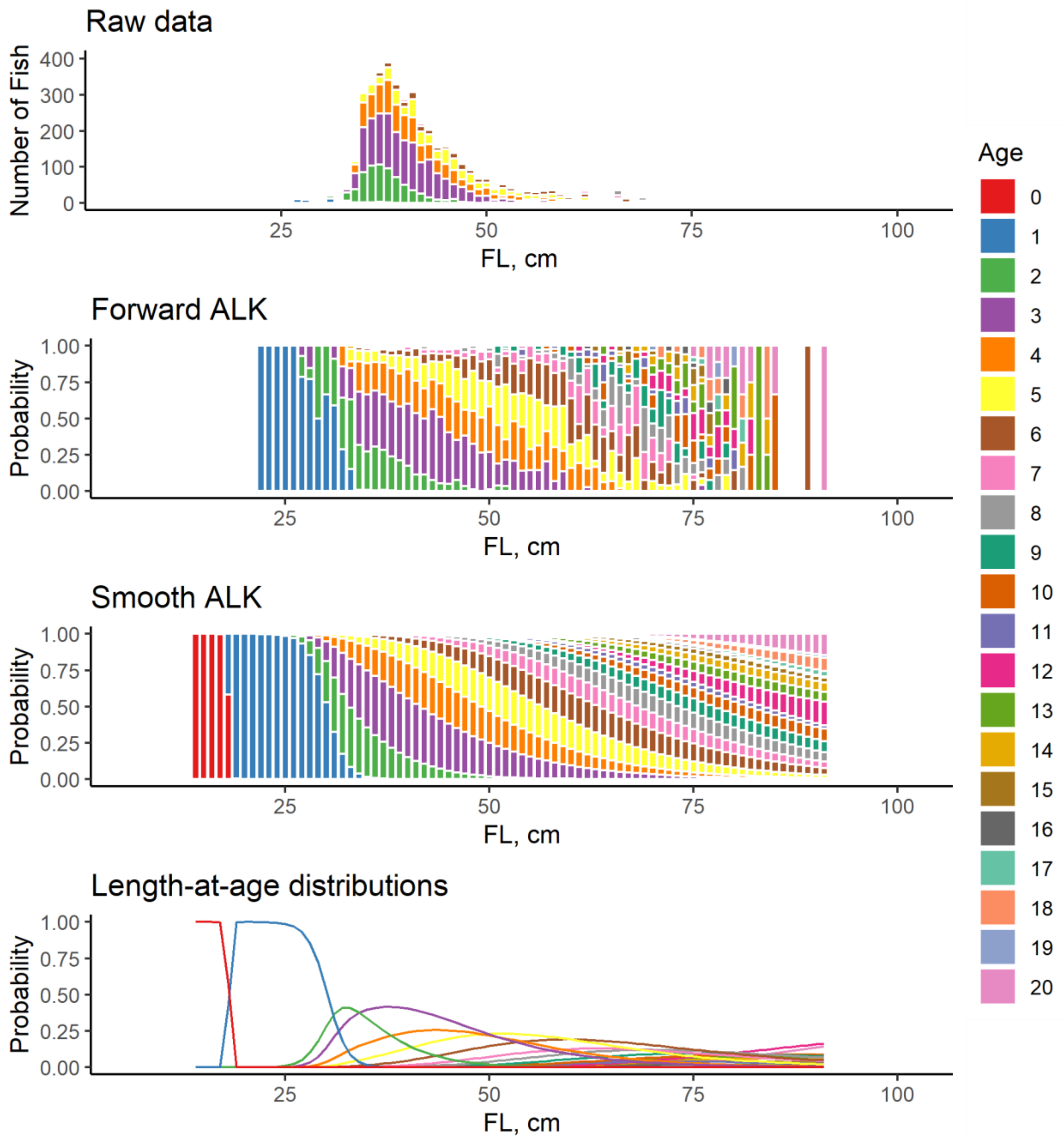

Figure 18. Age data and derived ALKs for 2005 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

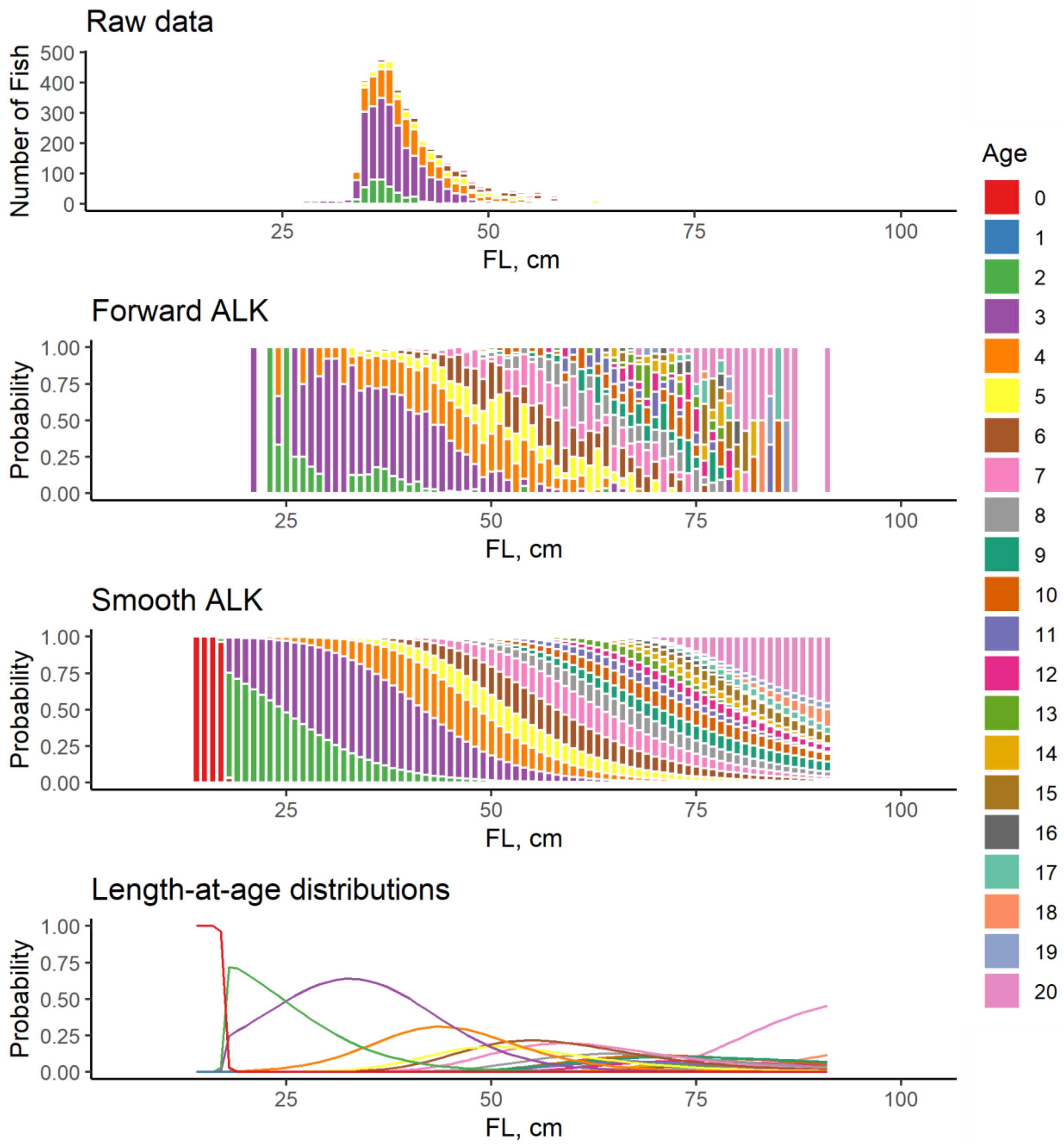

Figure 19. Age data and derived ALKs for 2006 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

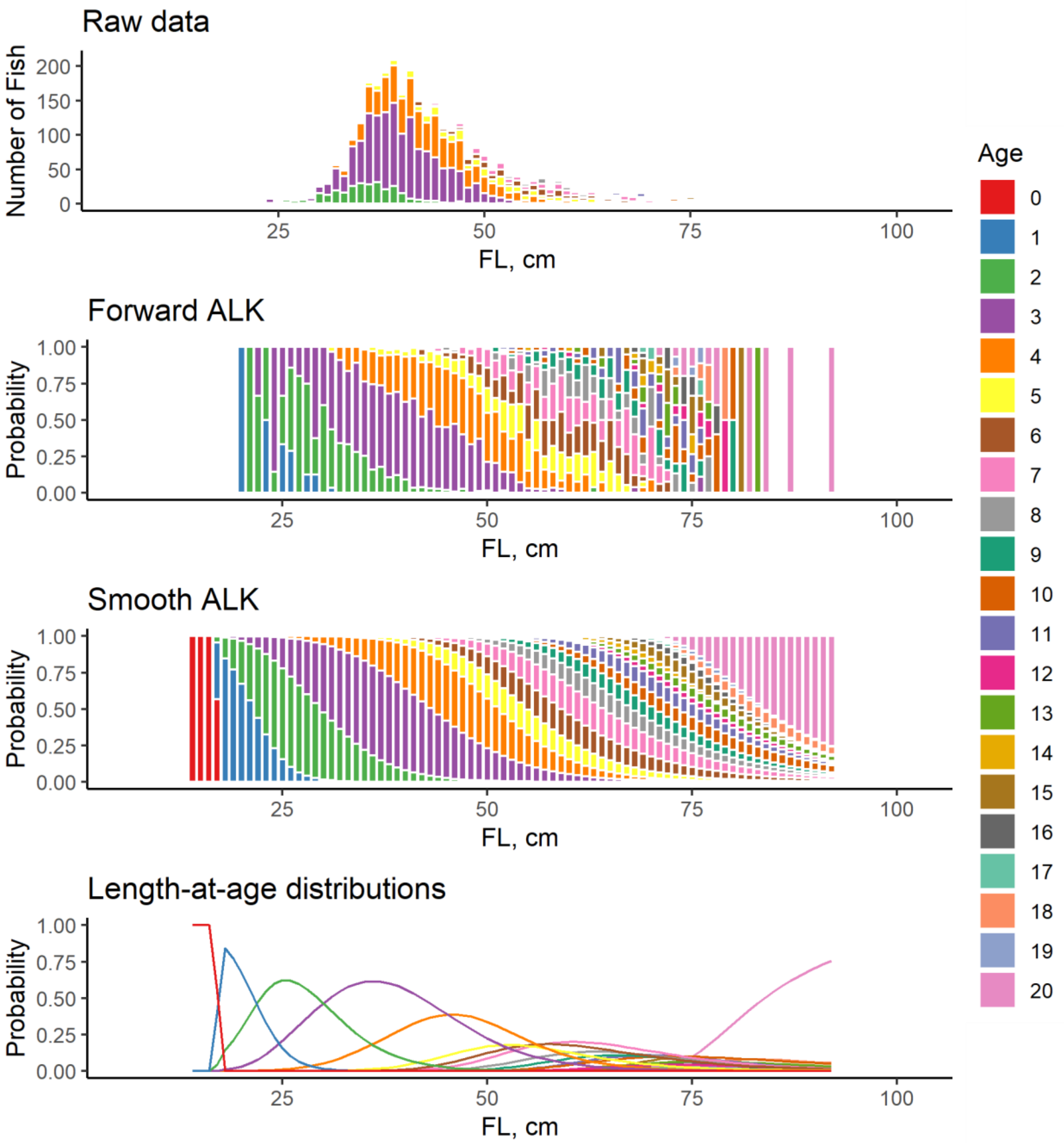

Figure 20. Age data and derived ALKs for 2007 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

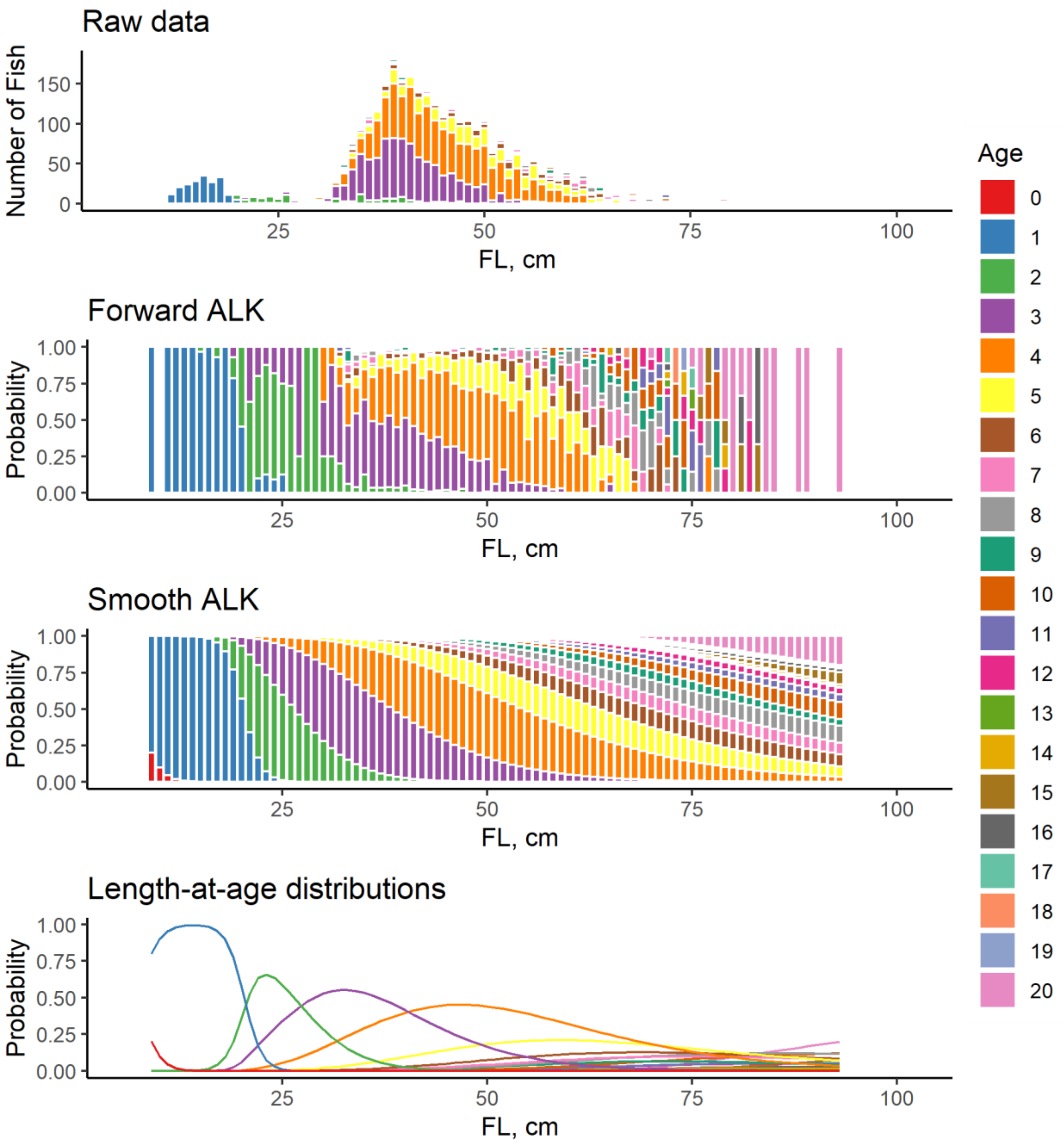

Figure 21. Age data and derived ALKs for 2008 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

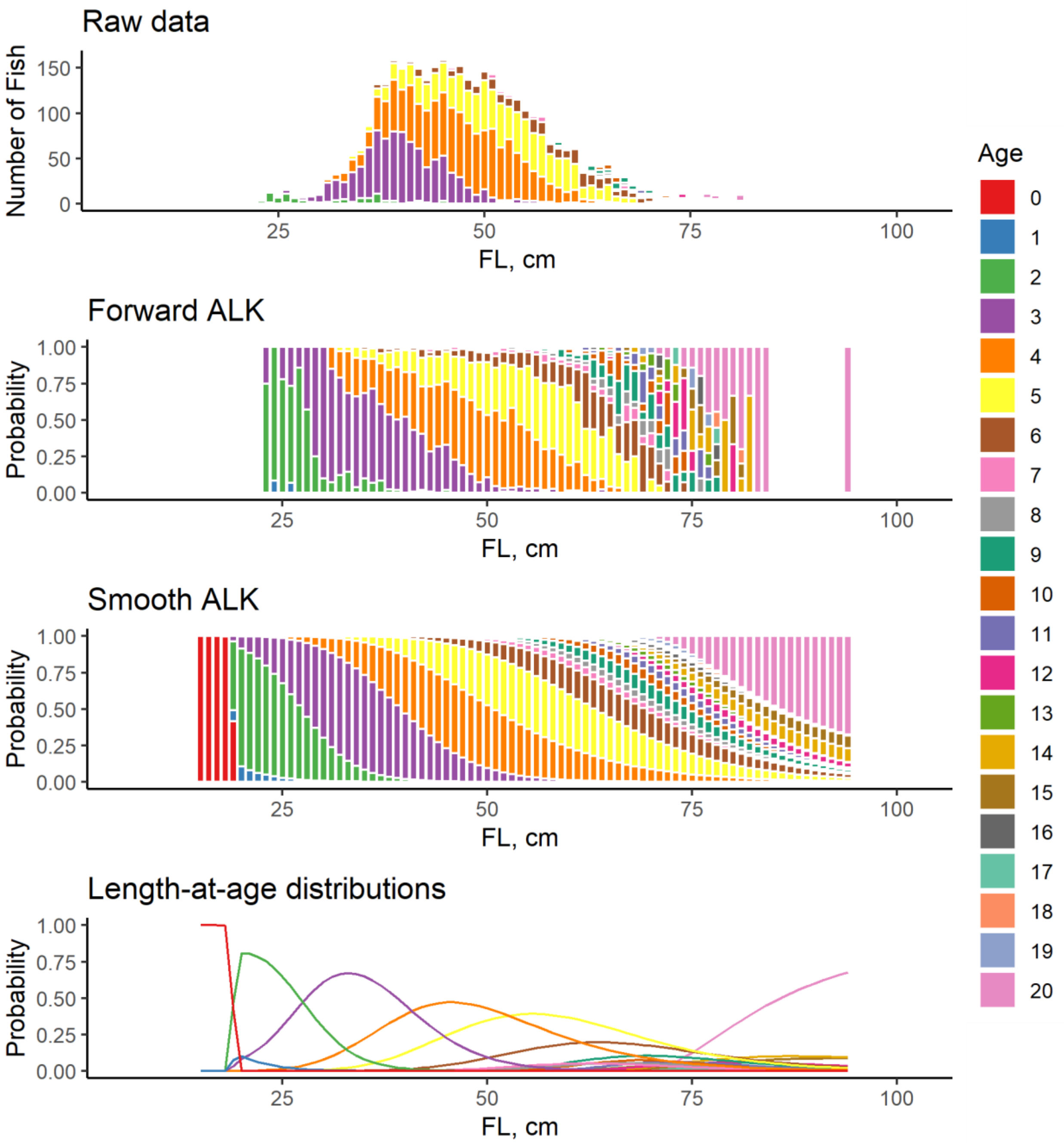

Figure 22. Age data and derived ALKs for 2009 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

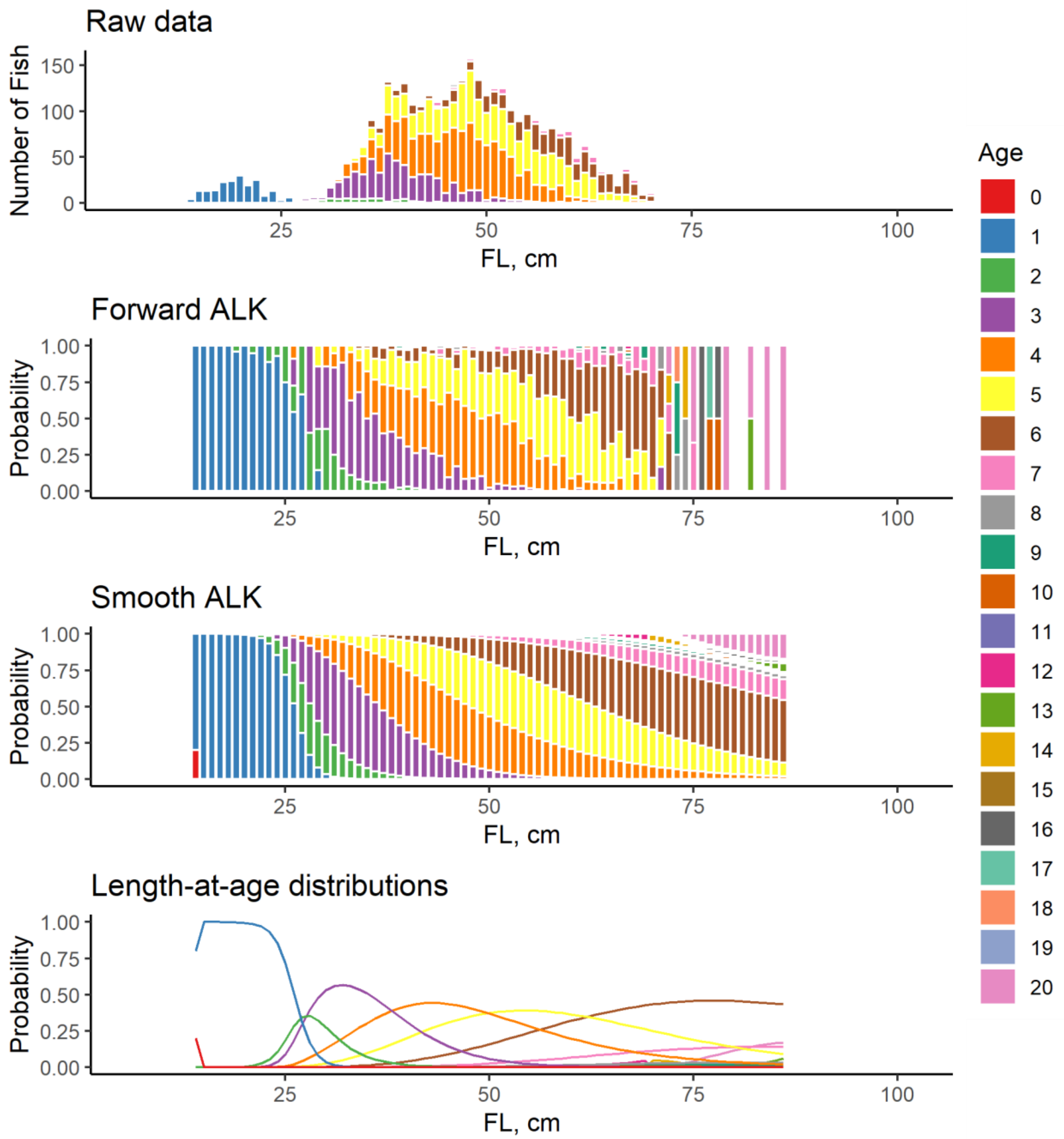

Figure 23. Age data and derived ALKs for 2010 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

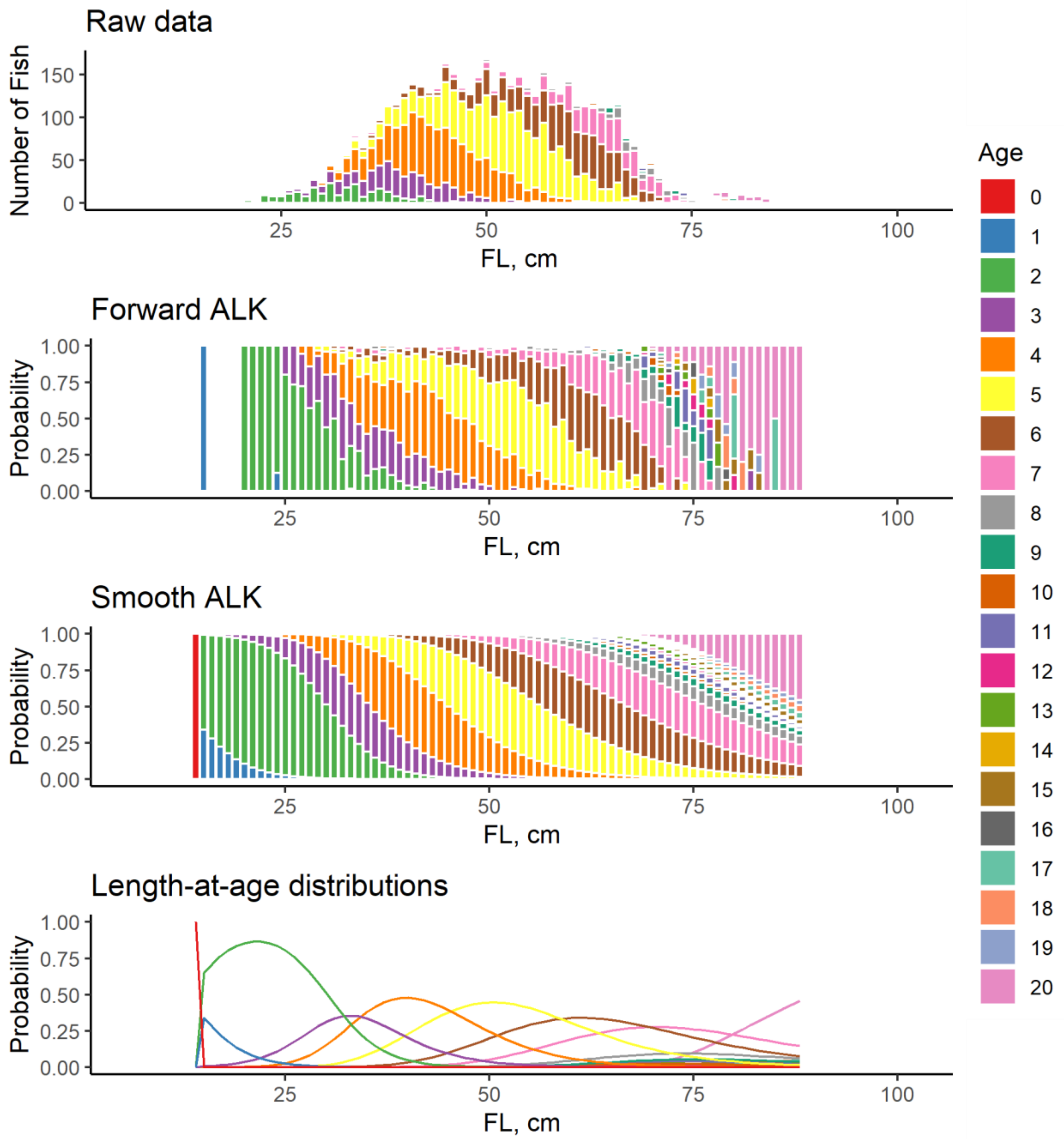

Figure 24. Age data and derived ALKs for 2011 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

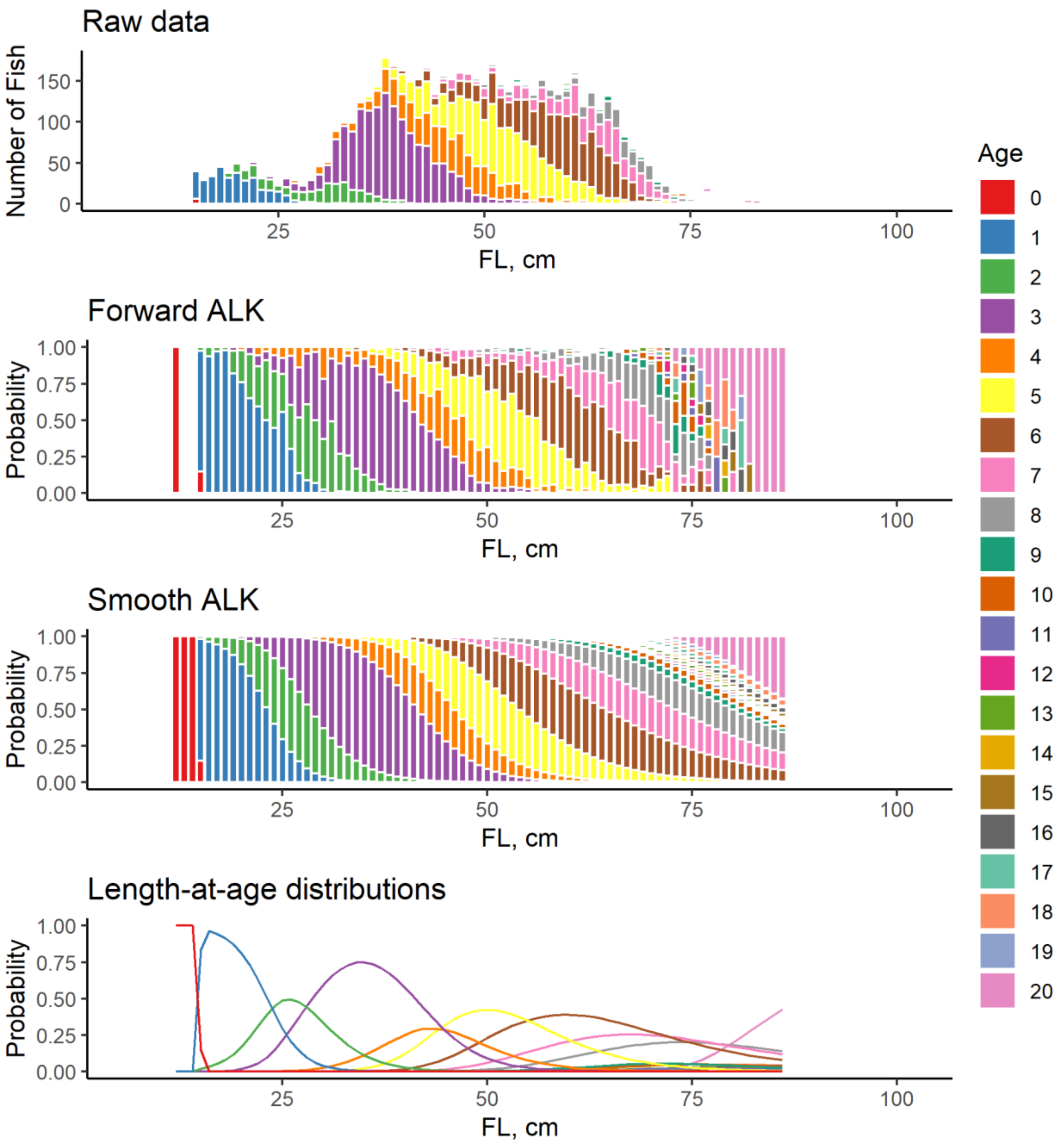

Figure 25. Age data and derived ALKs for 2012 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

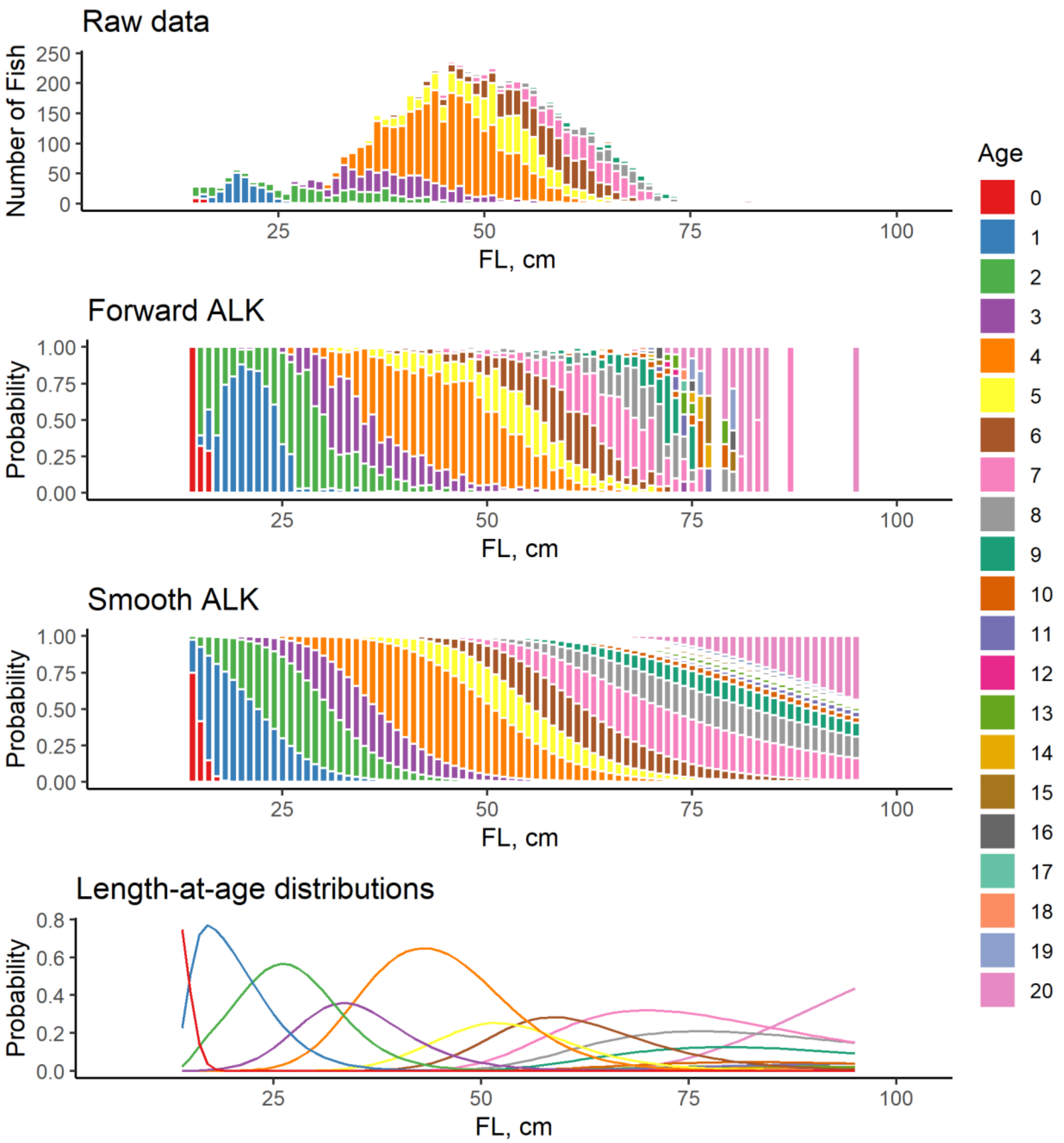

Figure 26. Age data and derived ALKs for 2013 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

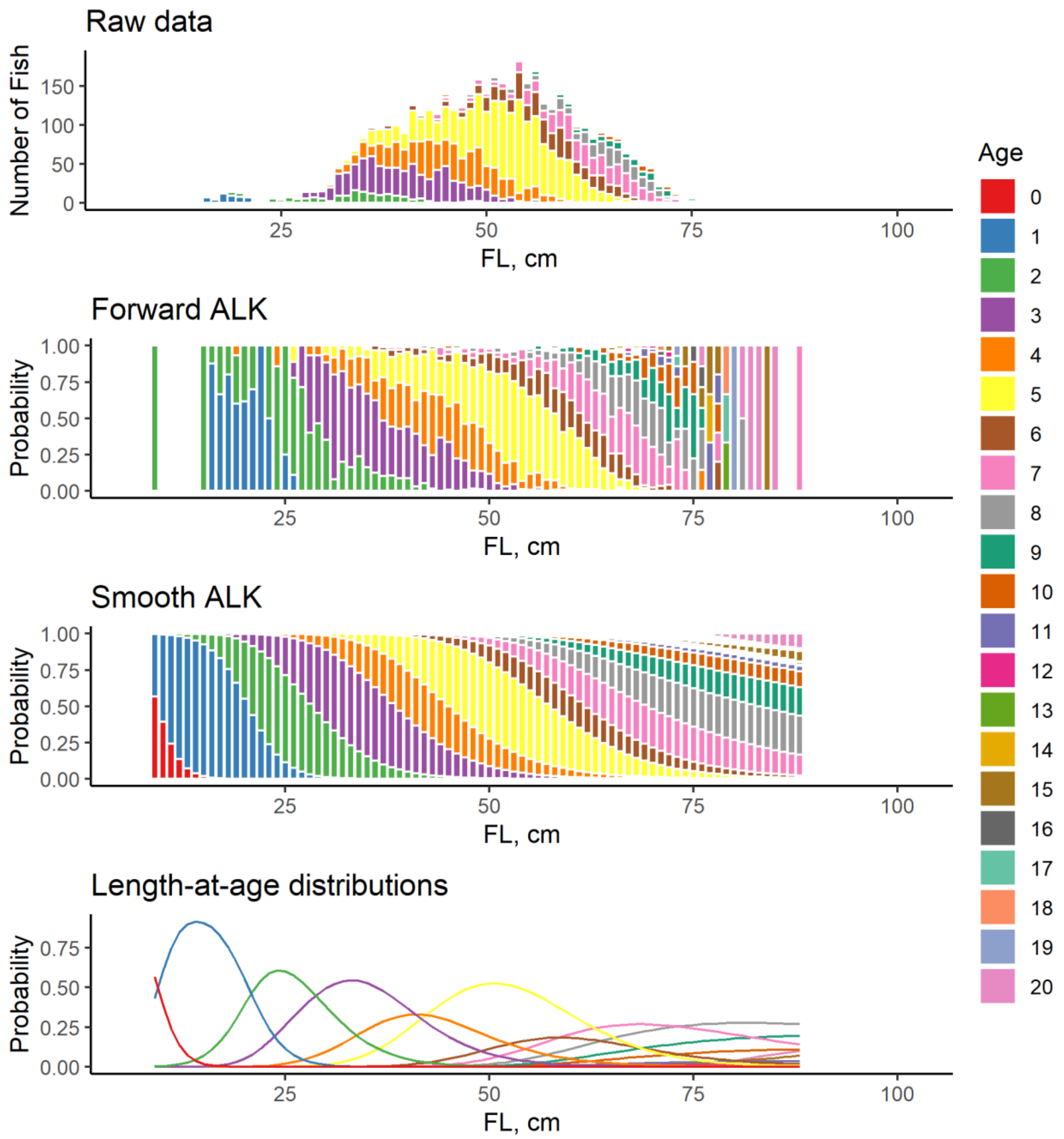

Figure 27. Age data and derived ALKs for 2014 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

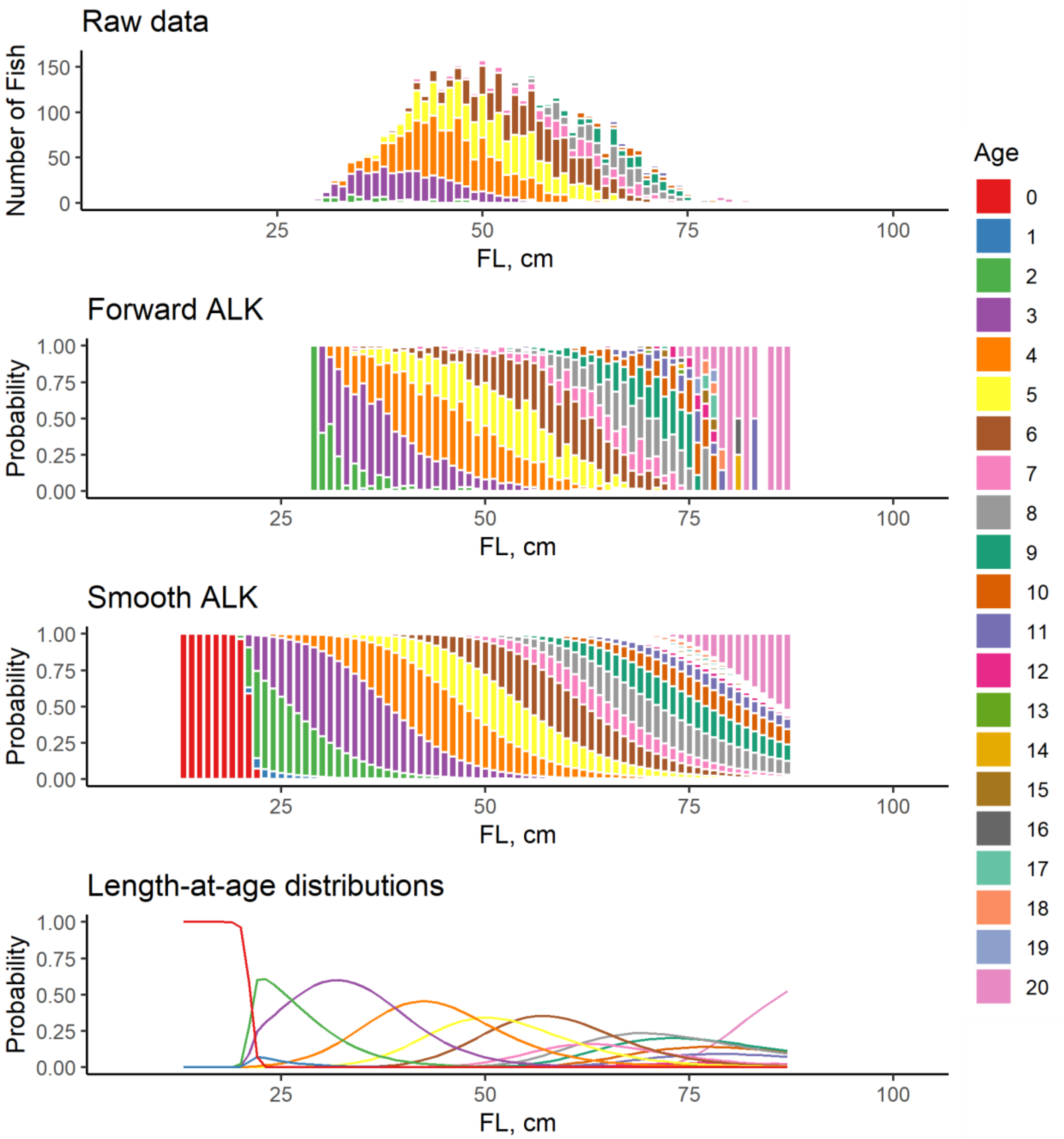

Figure 28. Age data and derived ALKs for 2015 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

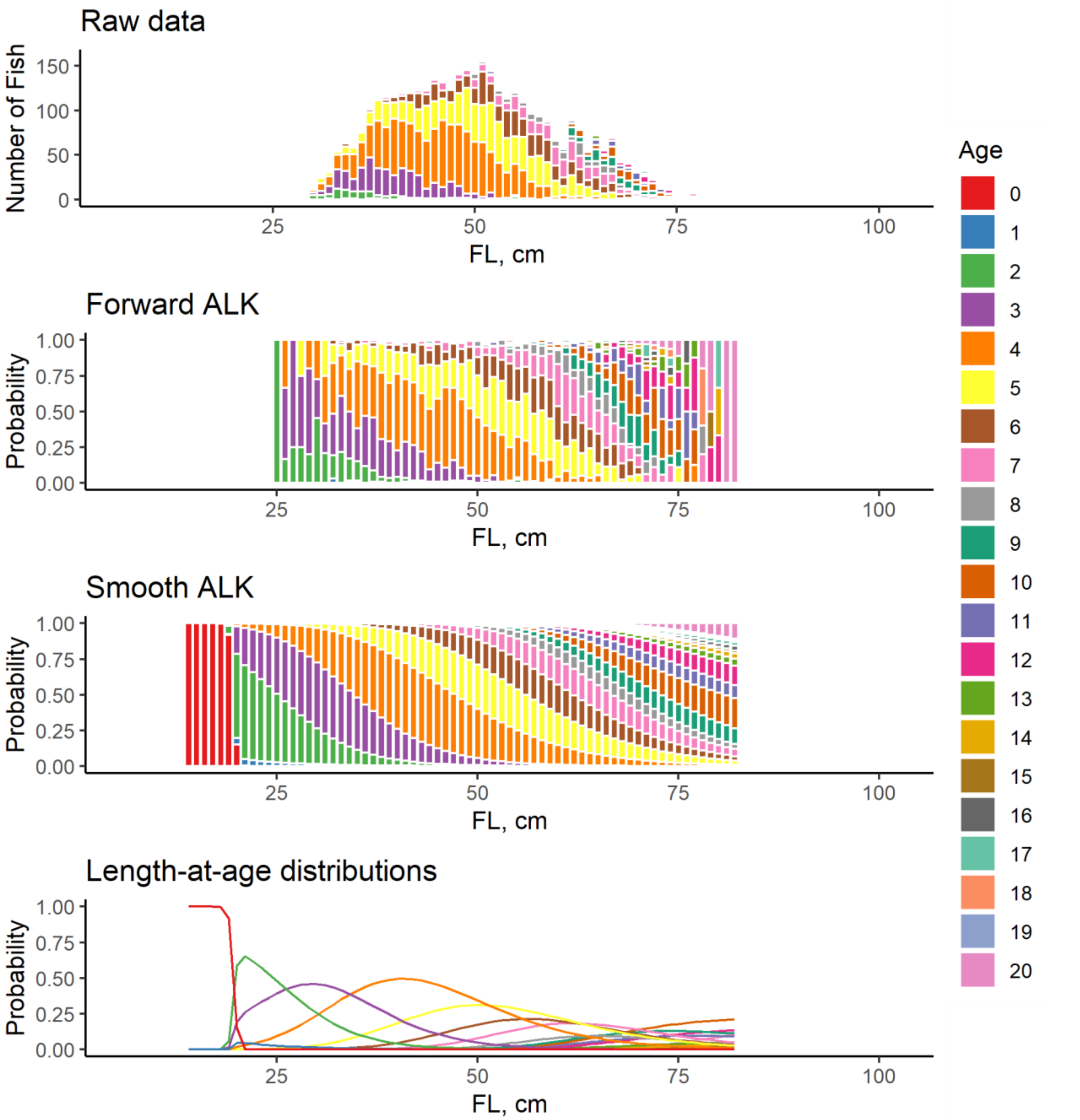

Figure 29. Age data and derived ALKs for 2016 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

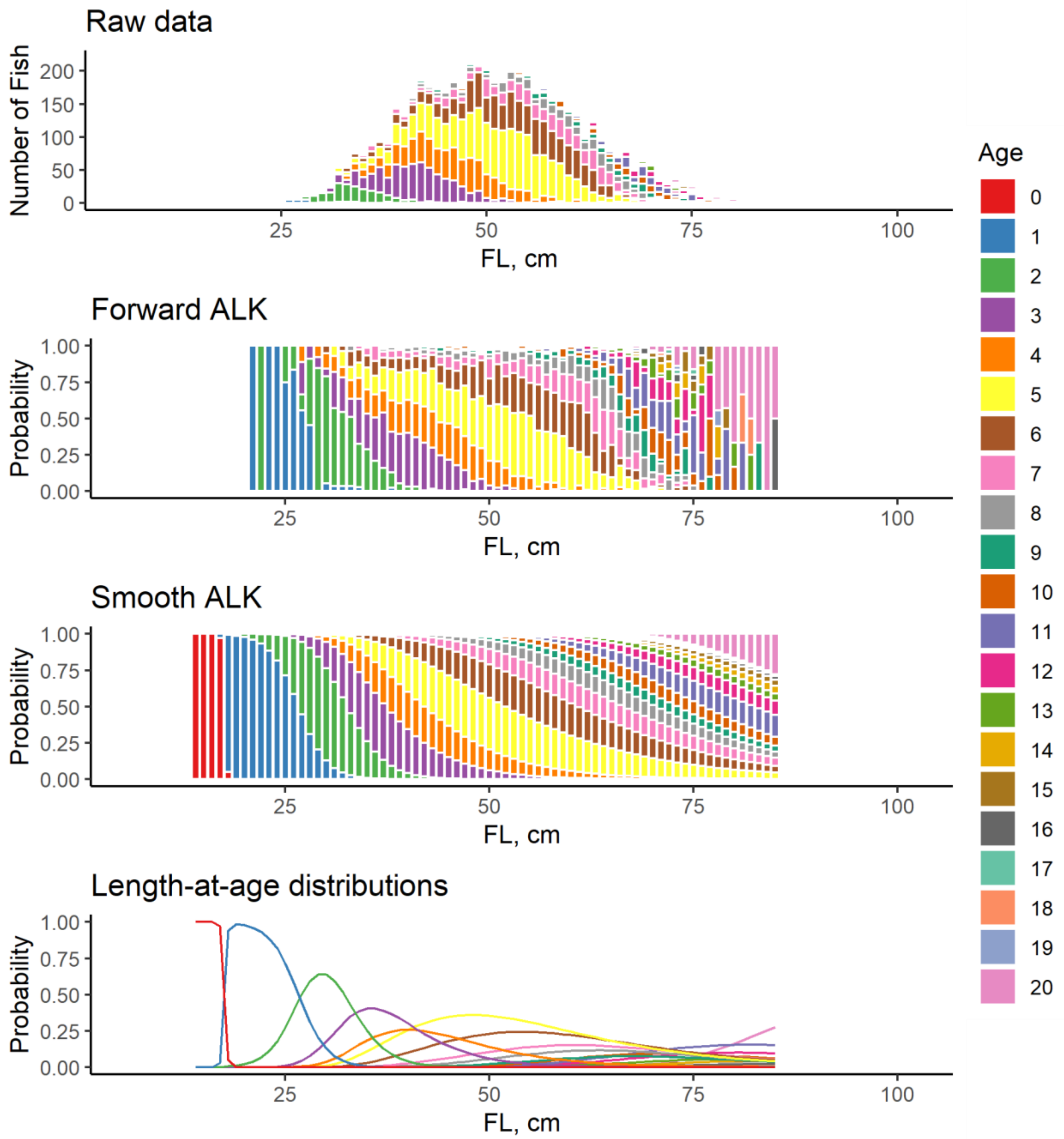

Figure 30. Age data and derived ALKs for 2017 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

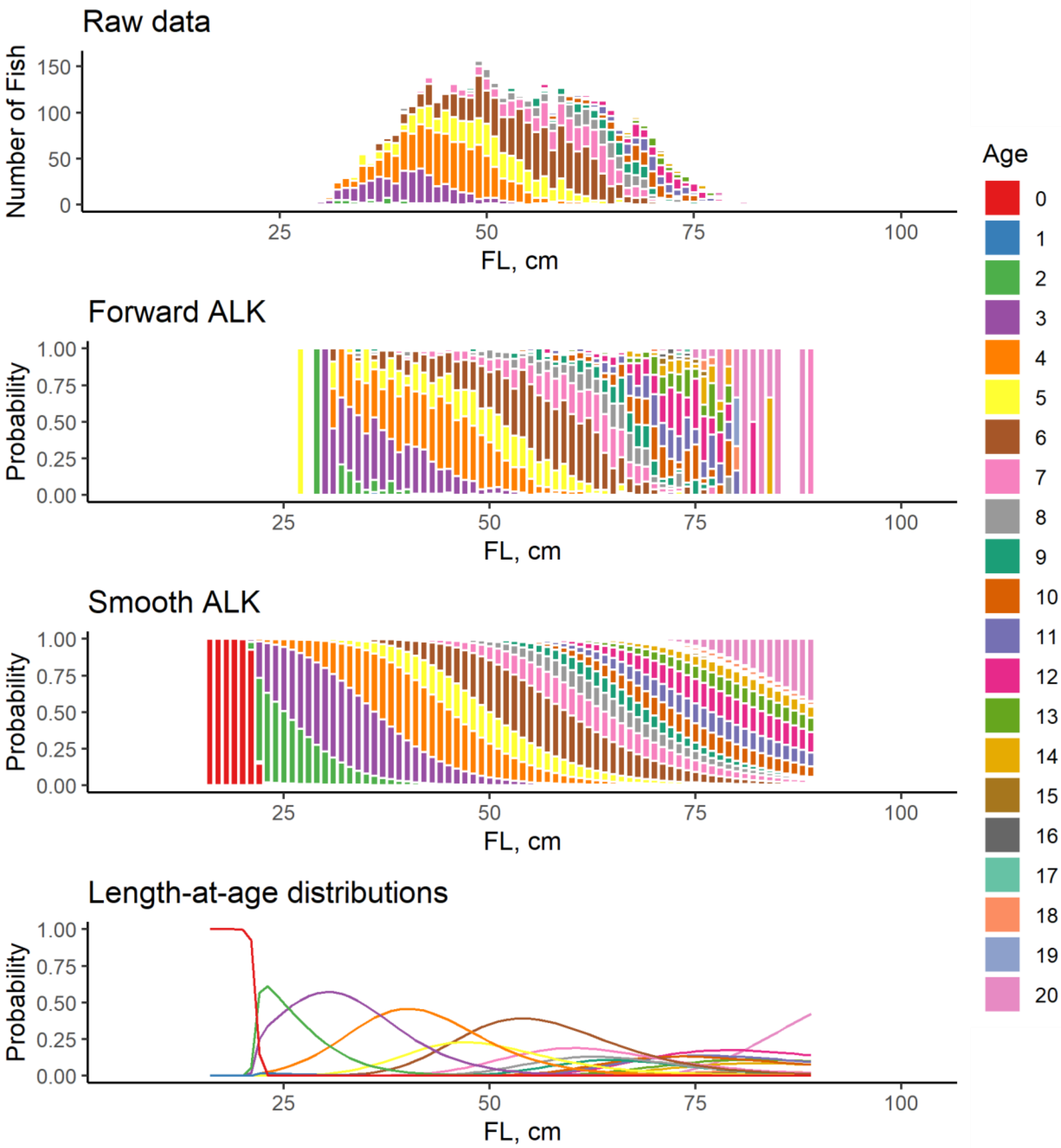

Figure 31. Age data and derived ALKs for 2018 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

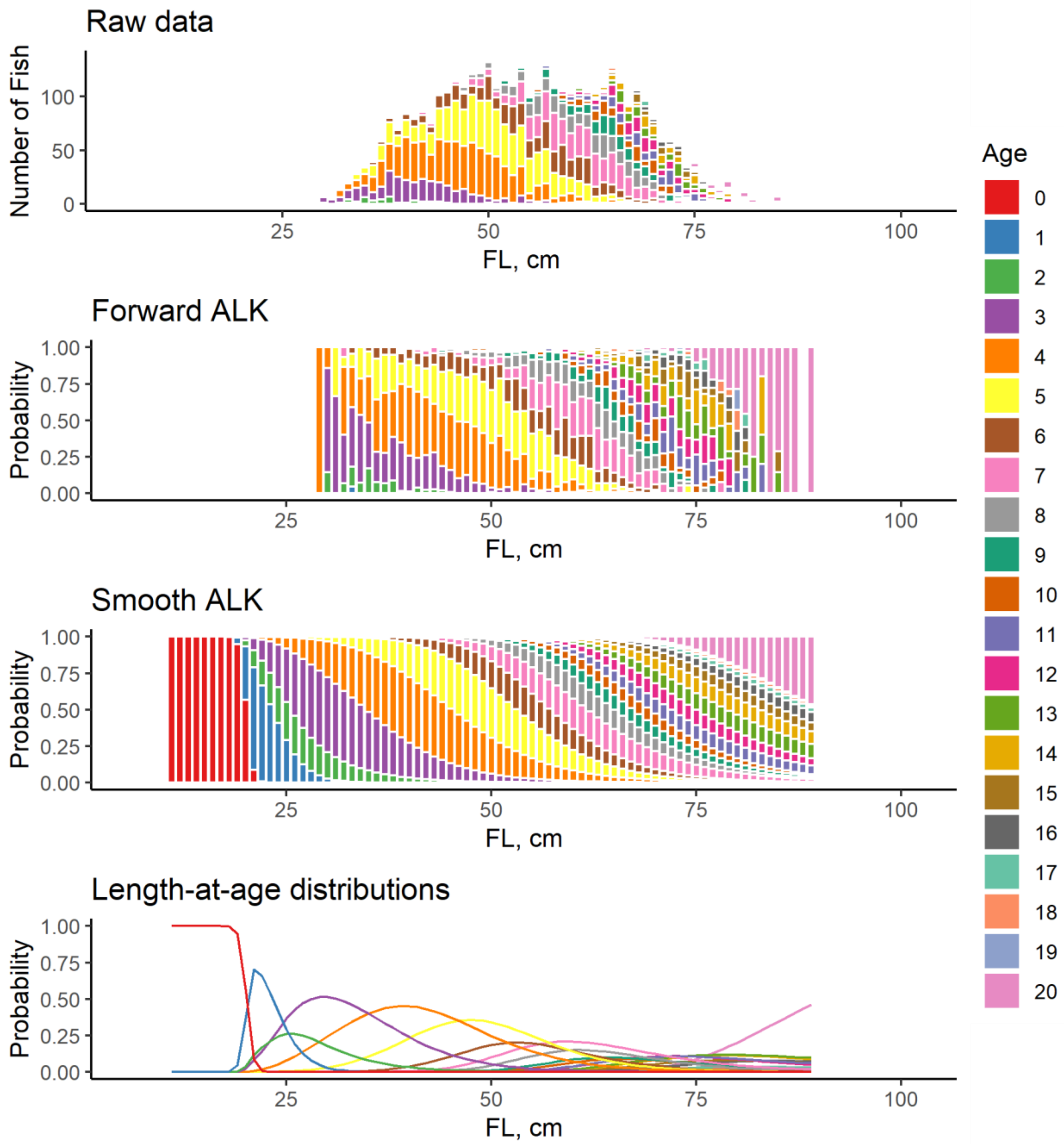

Figure 32. Age data and derived ALKs for 2019 in the W region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length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

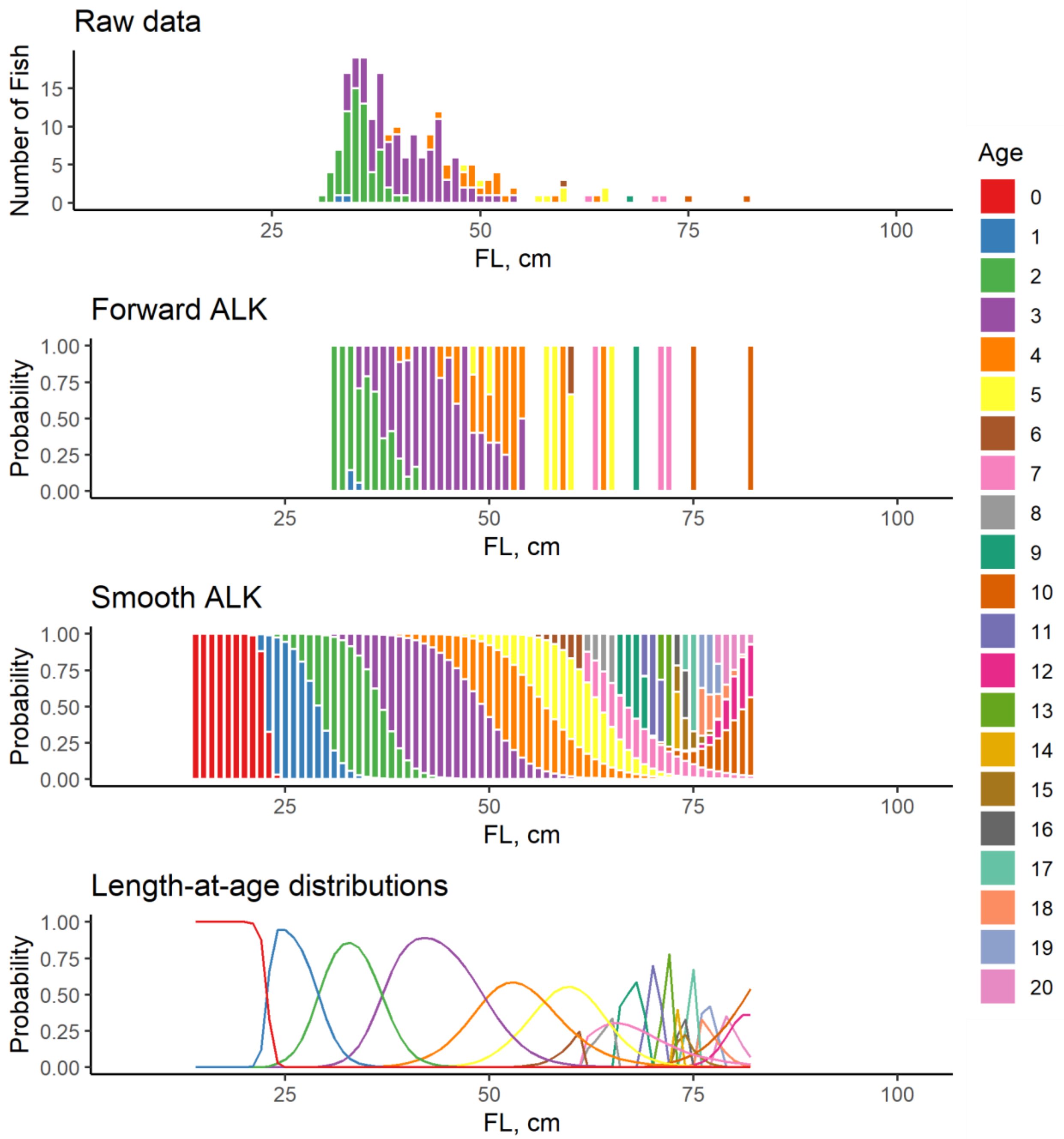

Figure 33. Age data and derived ALKs for 1996 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

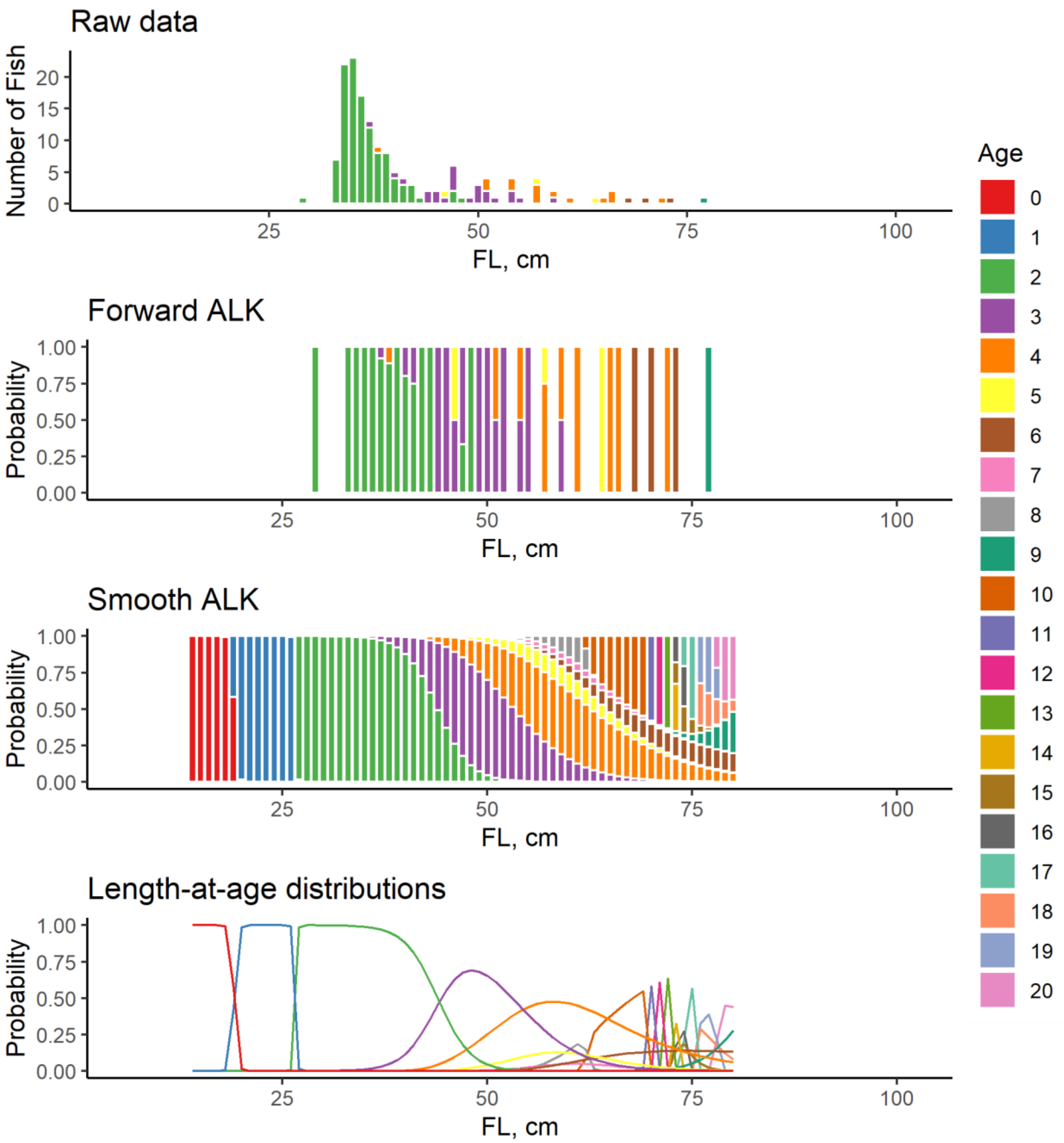

Figure 34. Age data and derived ALKs for 1997 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

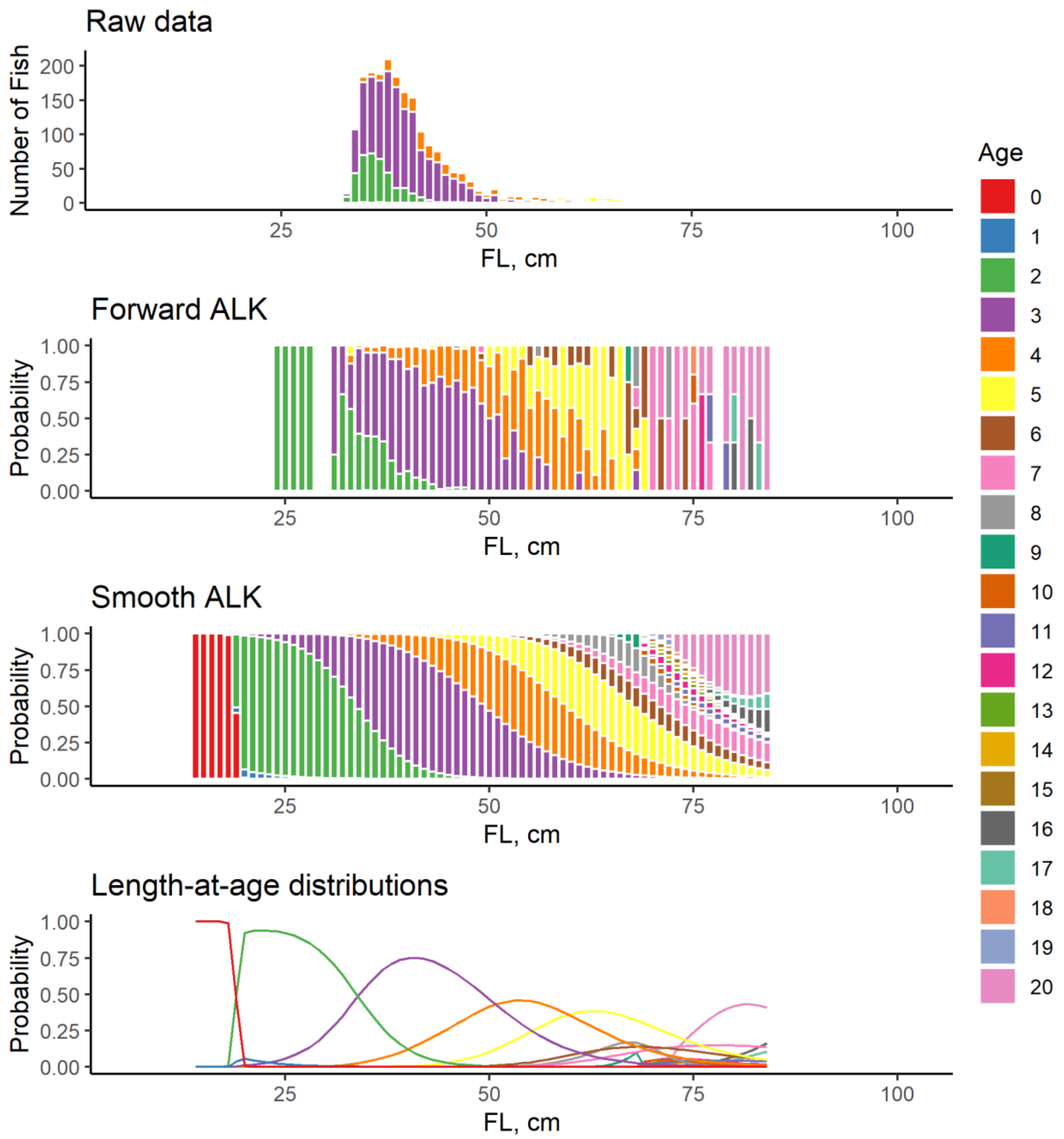

Figure 35. Age data and derived ALKs for 1998 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

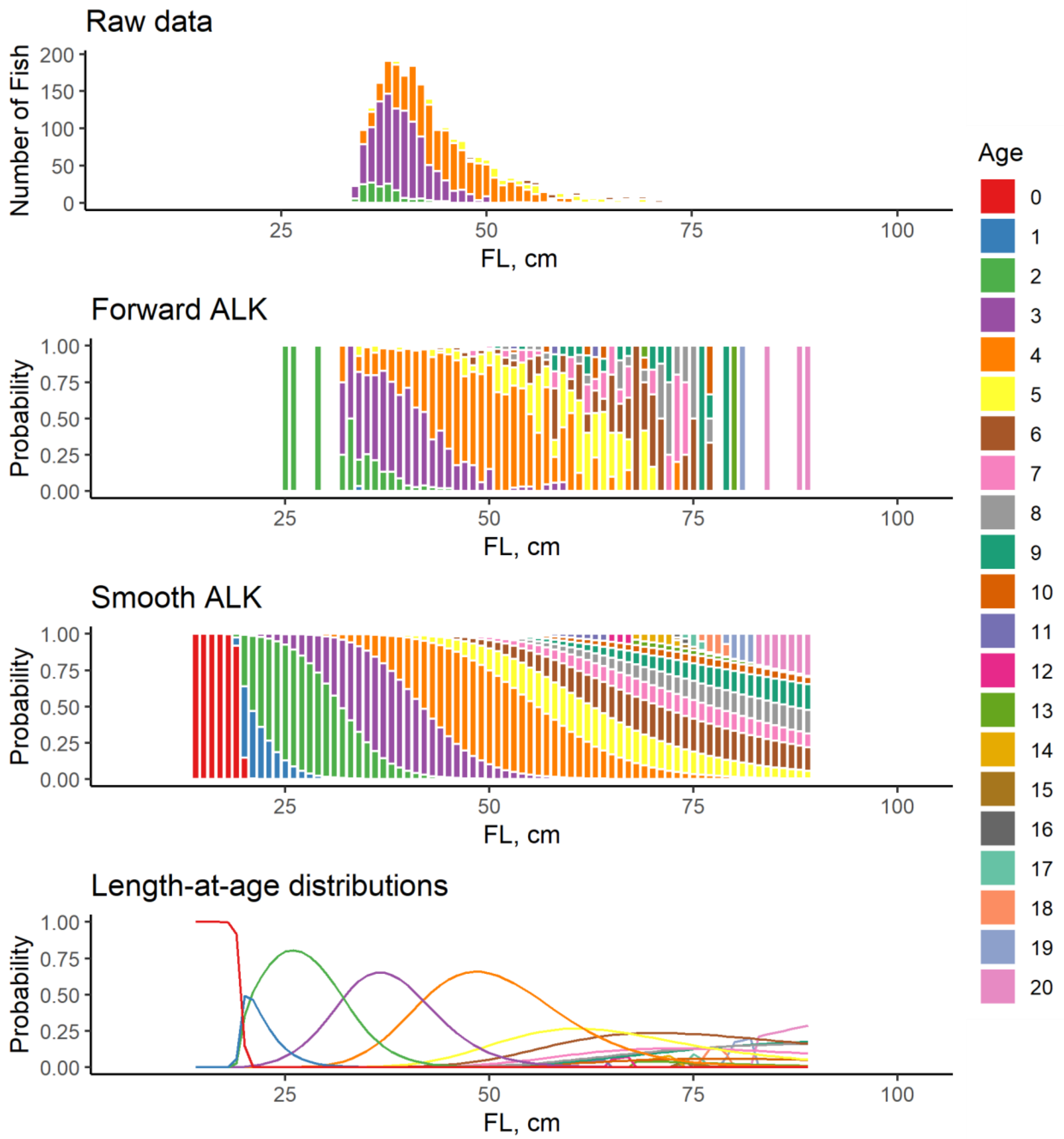

Figure 36. Age data and derived ALKs for 1999 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

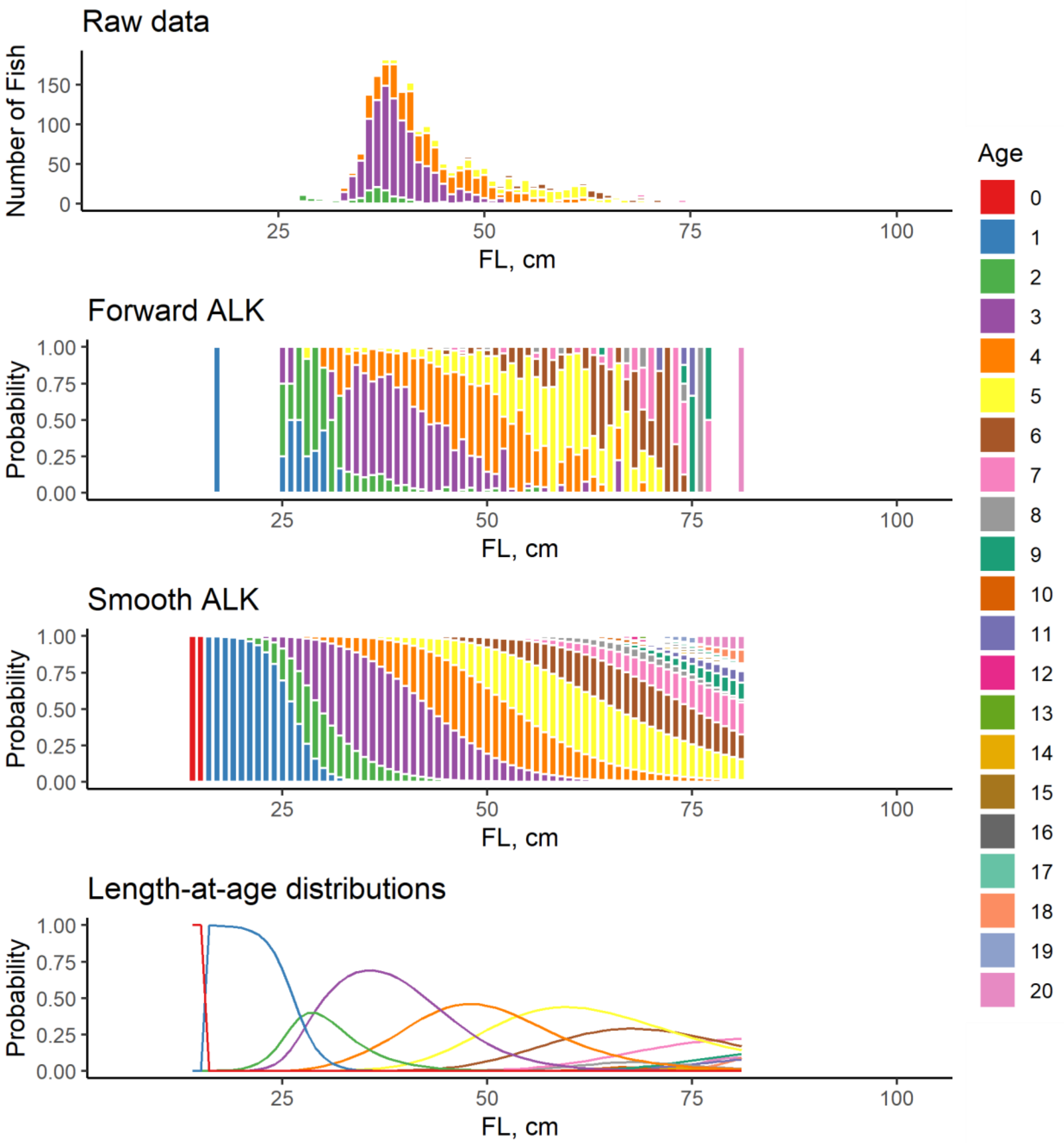

Figure 37. Age data and derived ALKs for 2000 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

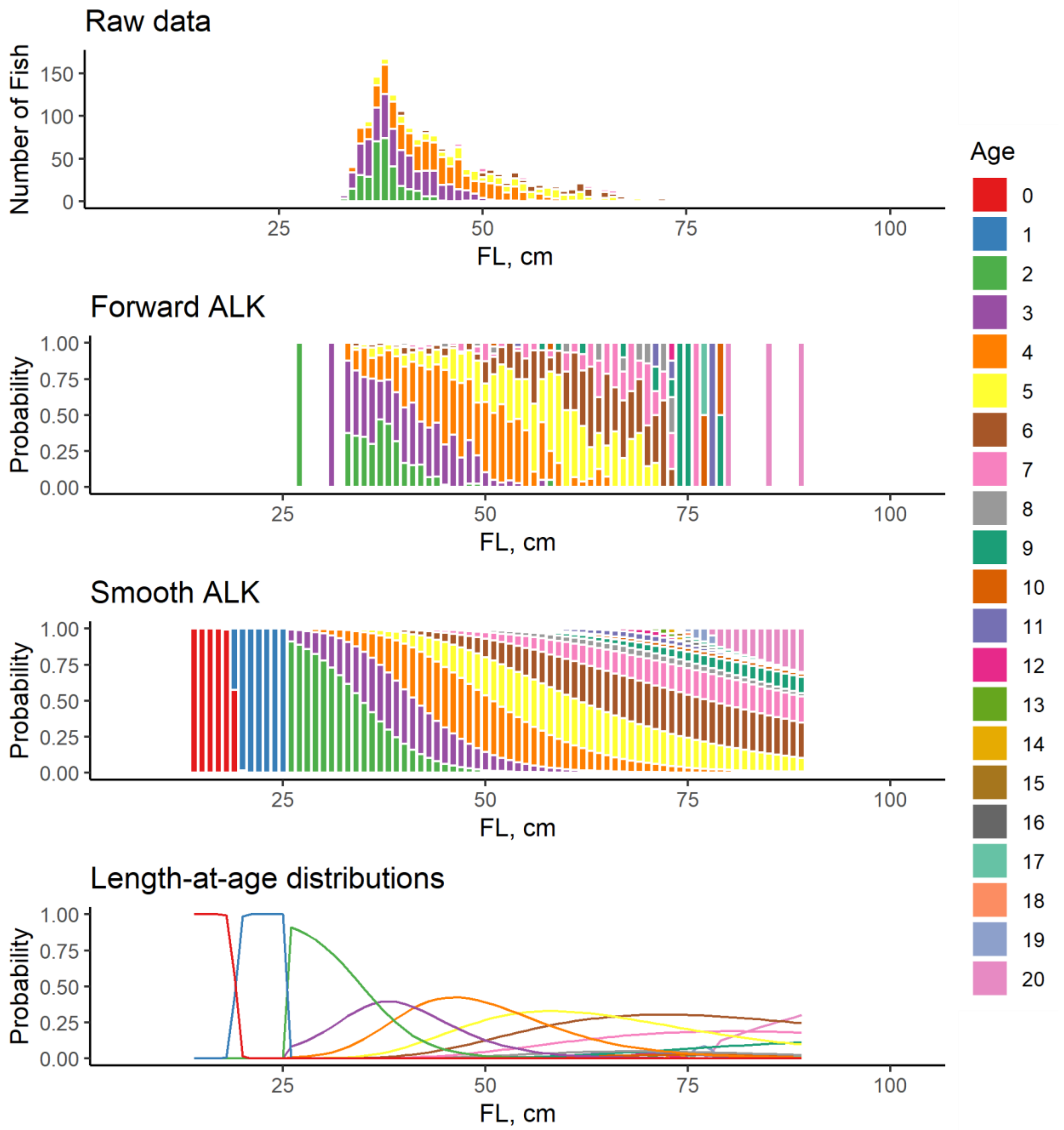

Figure 38. Age data and derived ALKs for 2001 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

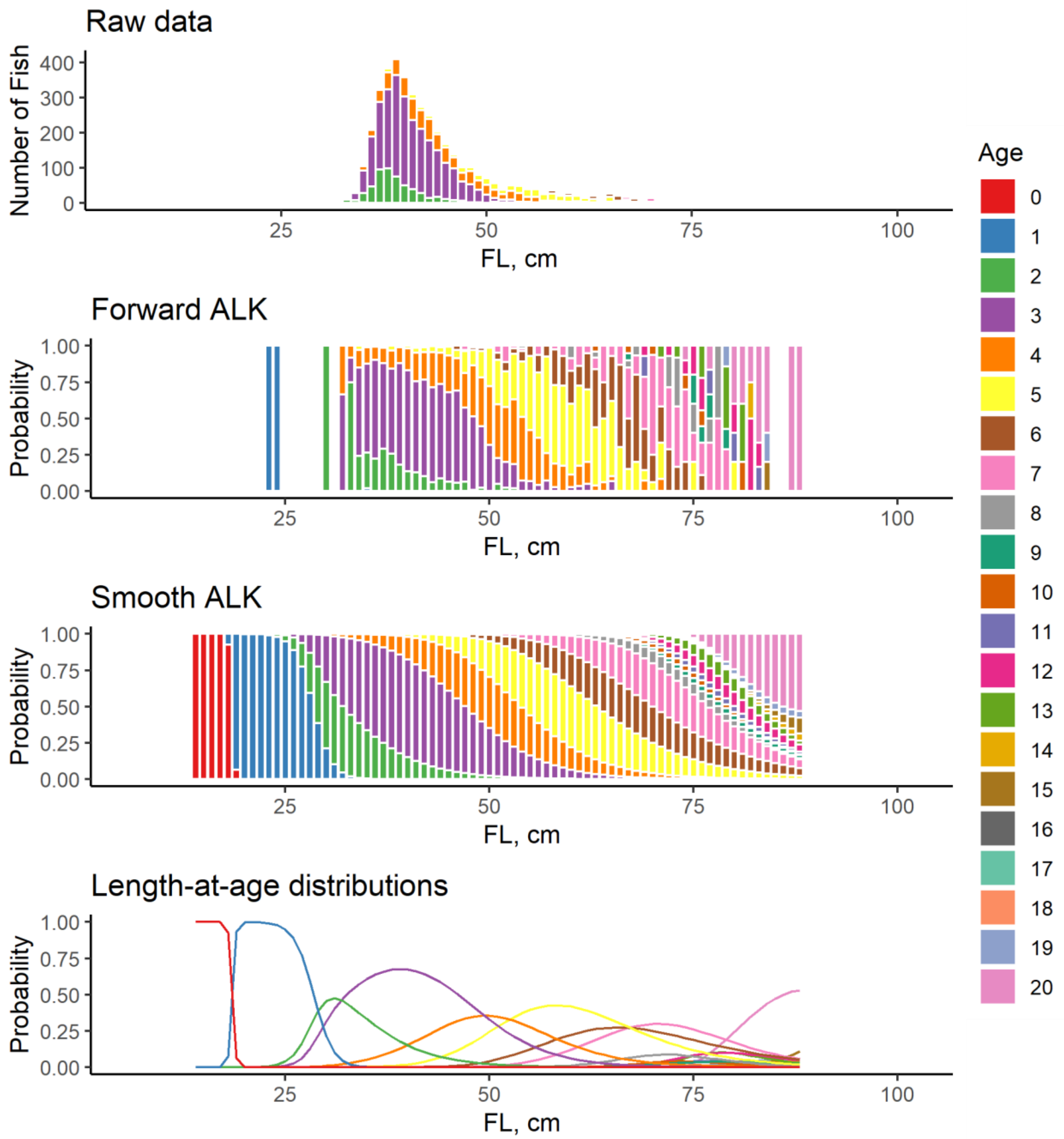

Figure 39. Age data and derived ALKs for 2002 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

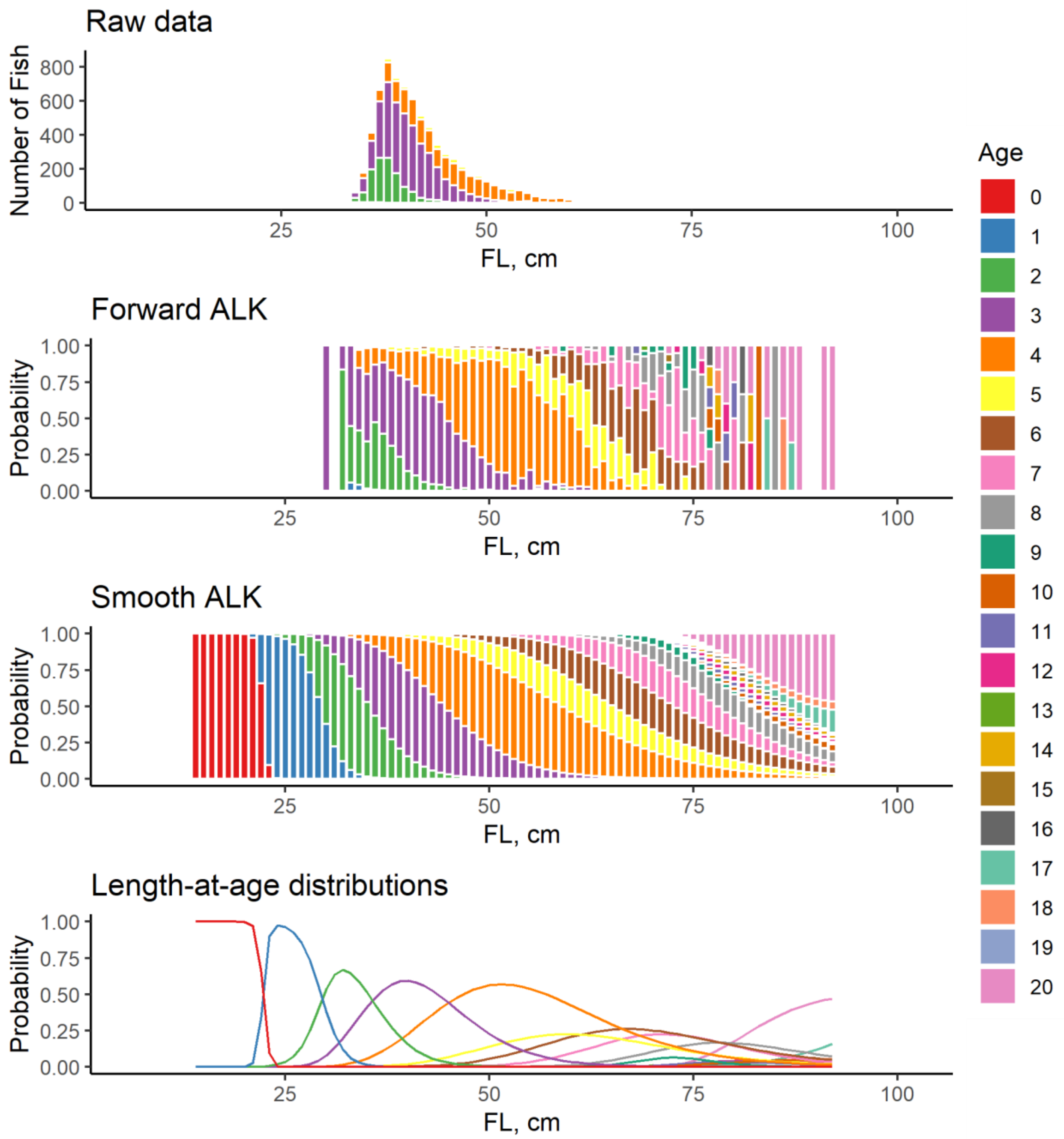

Figure 40. Age data and derived ALKs for 2003 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

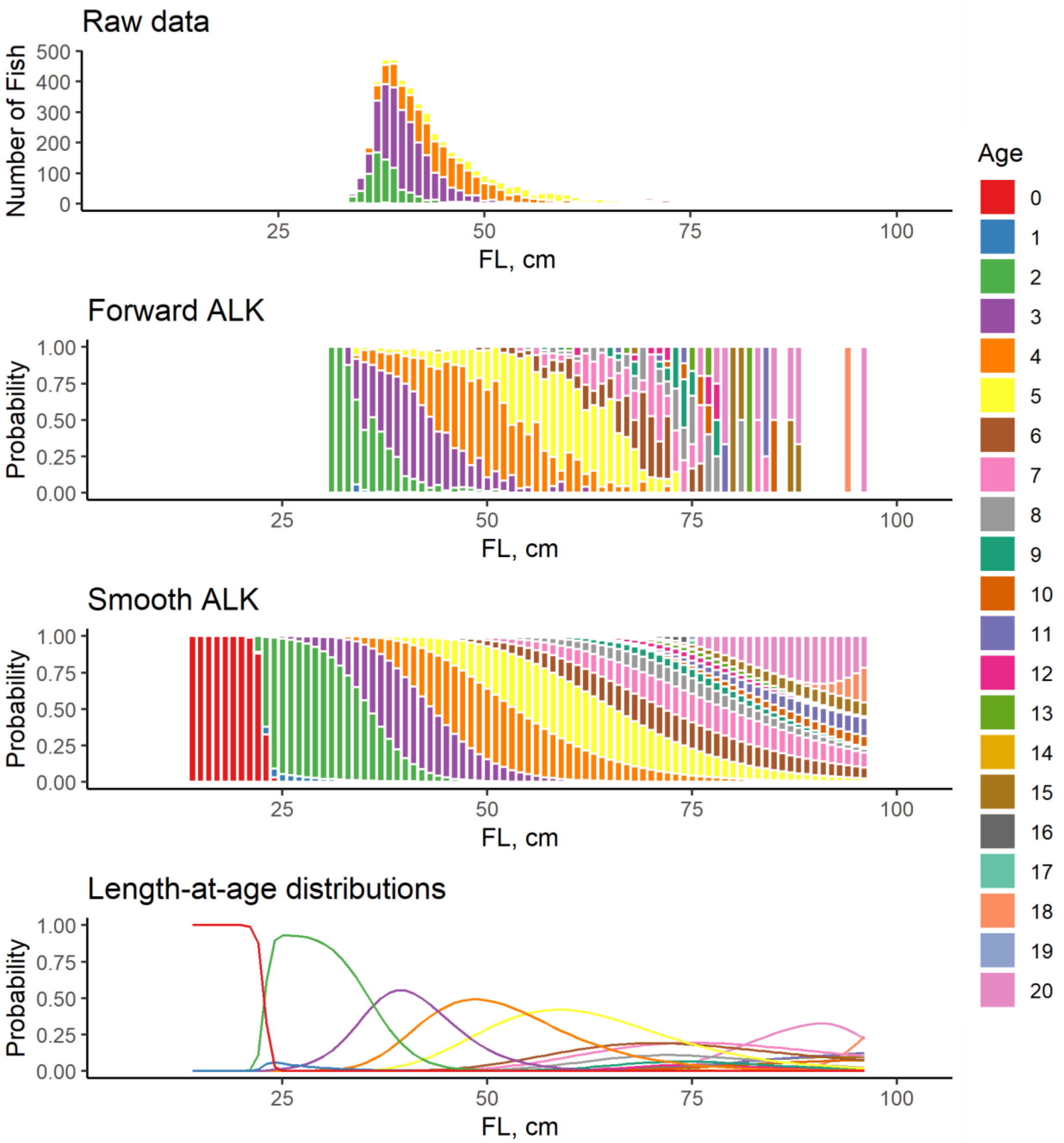

Figure 41. Age data and derived ALKs for 2004 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

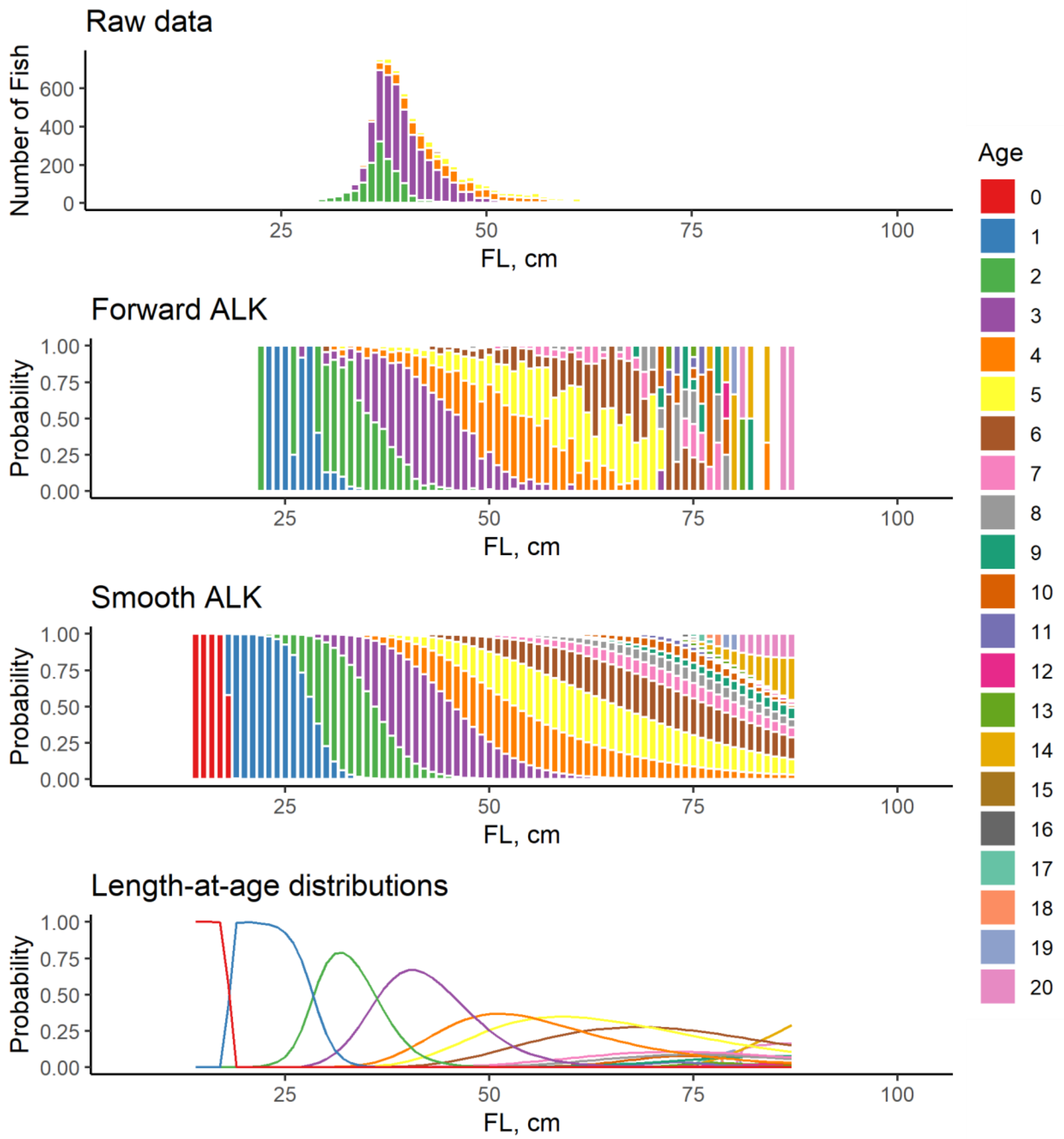

Figure 42. Age data and derived ALKs for 2005 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

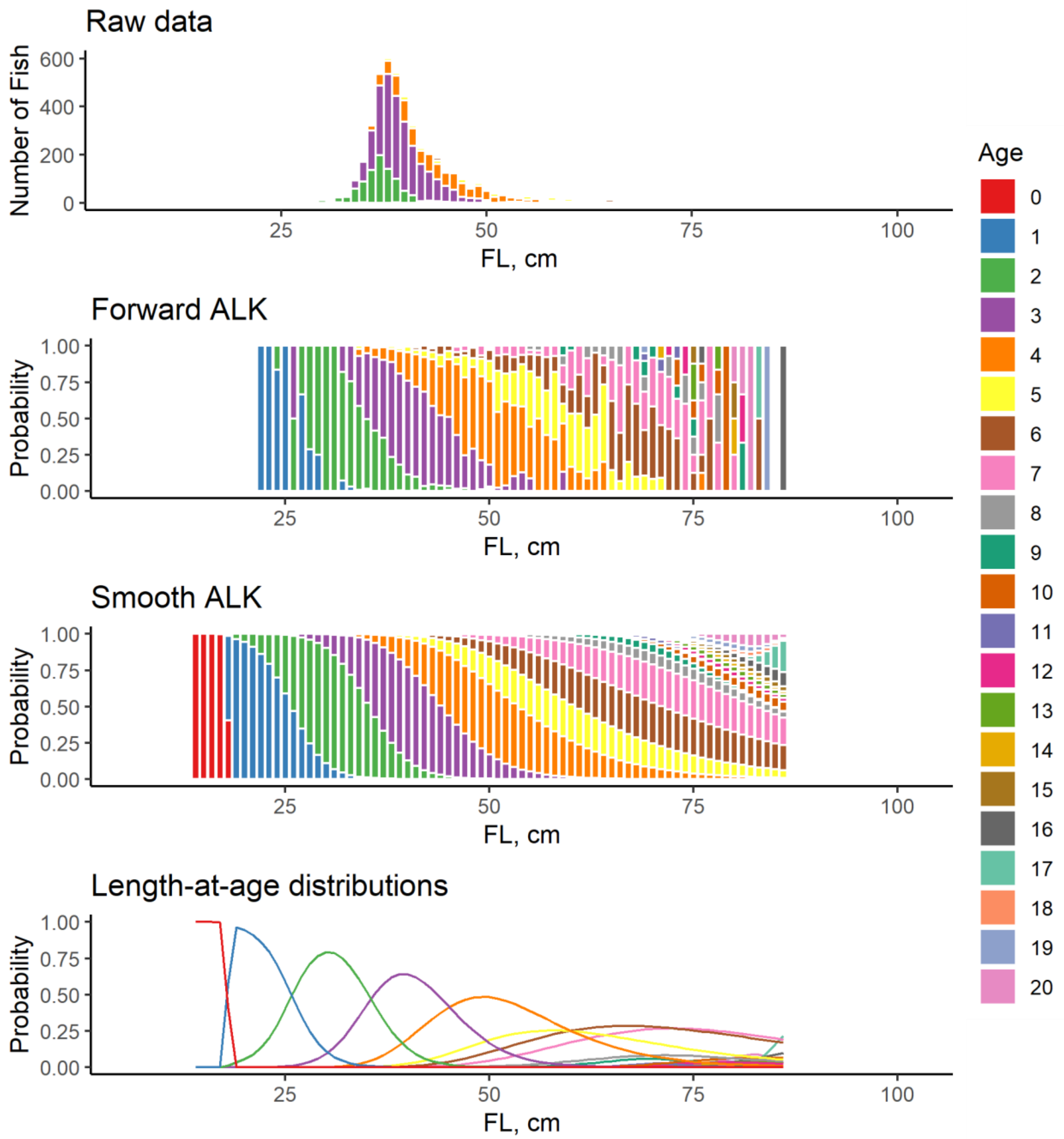

Figure 43. Age data and derived ALKs for 2006 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

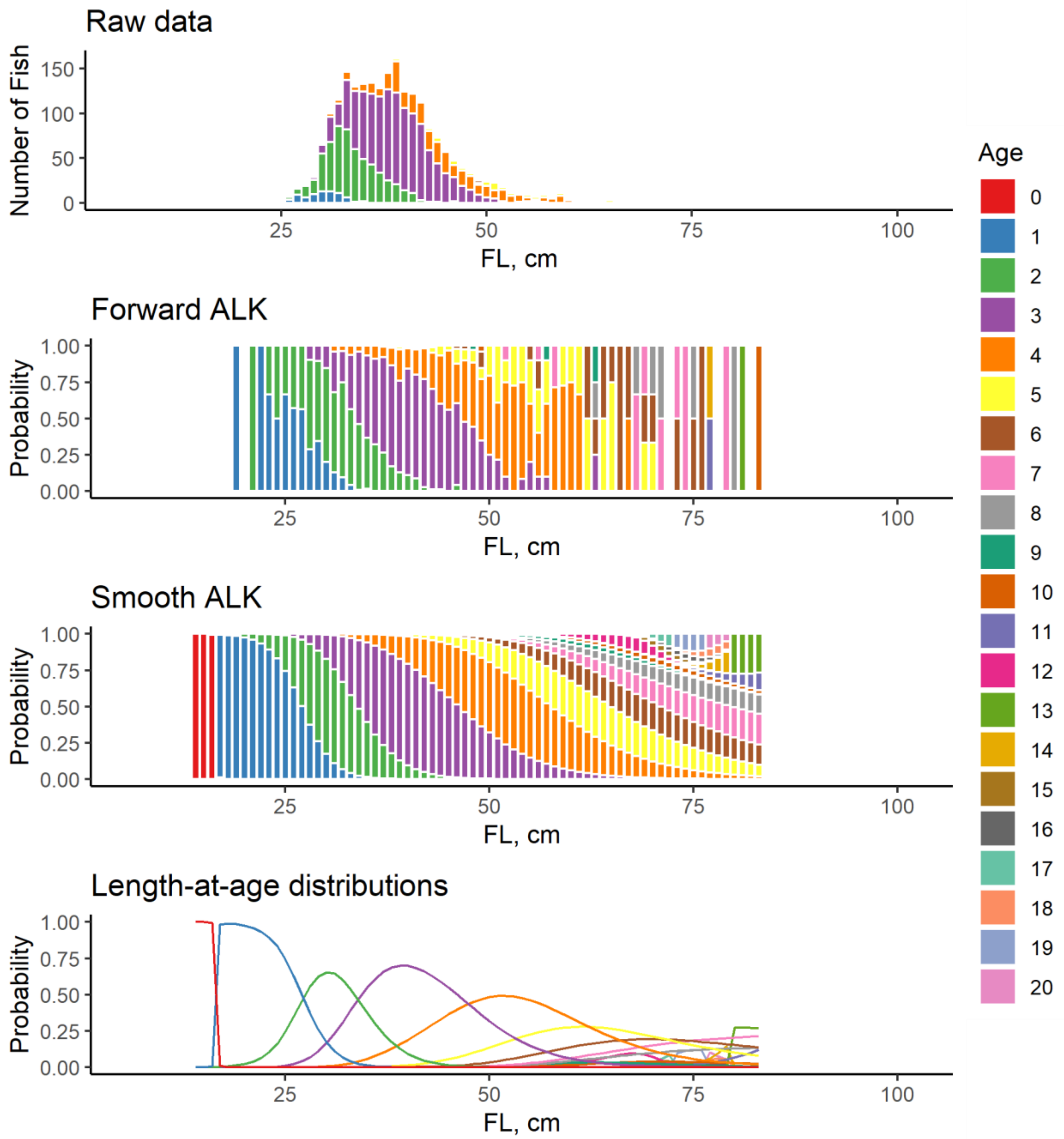

Figure 44. Age data and derived ALKs for 2007 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

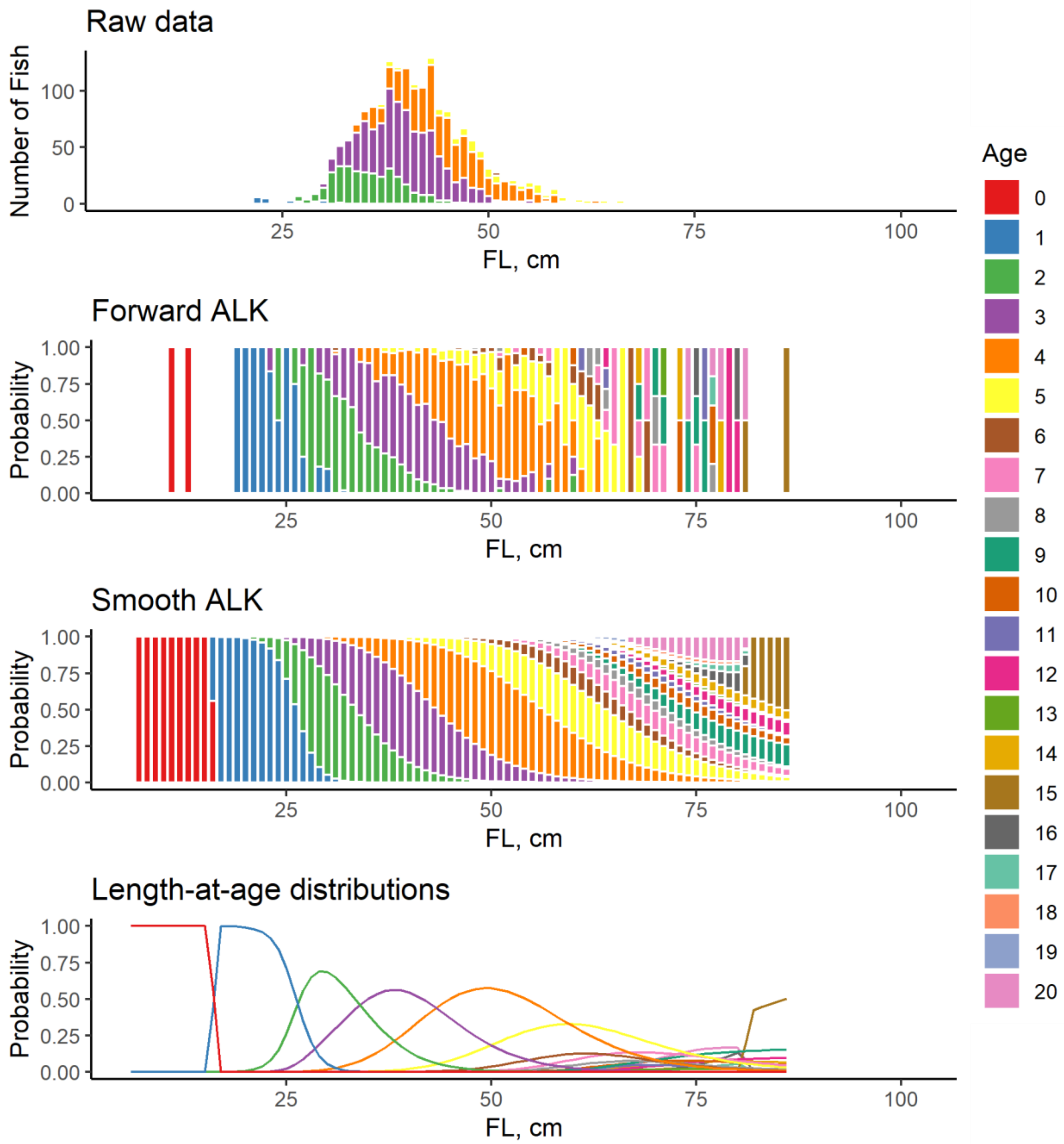

Figure 45. Age data and derived ALKs for 2008 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

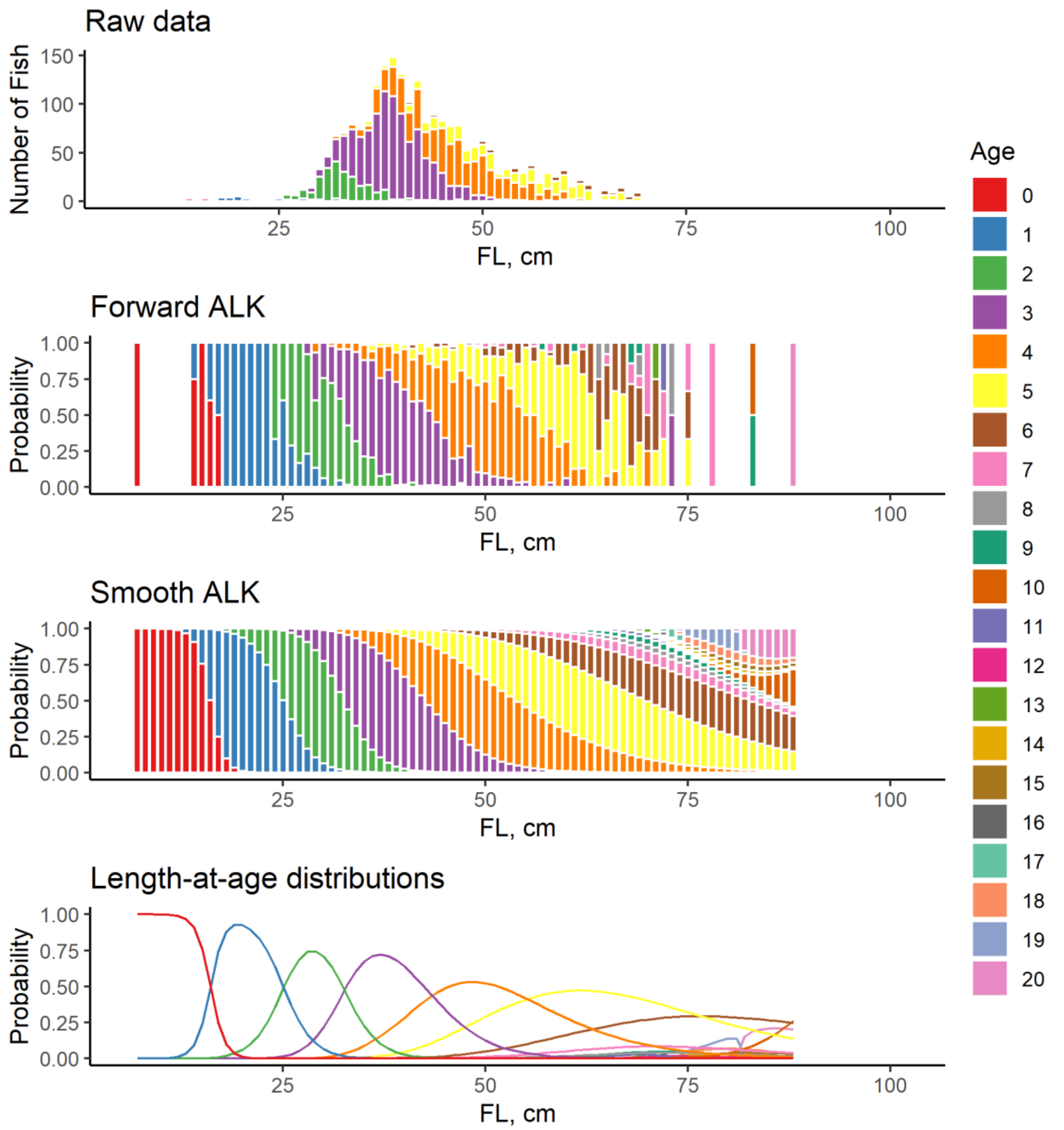

Figure 46. Age data and derived ALKs for 2009 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

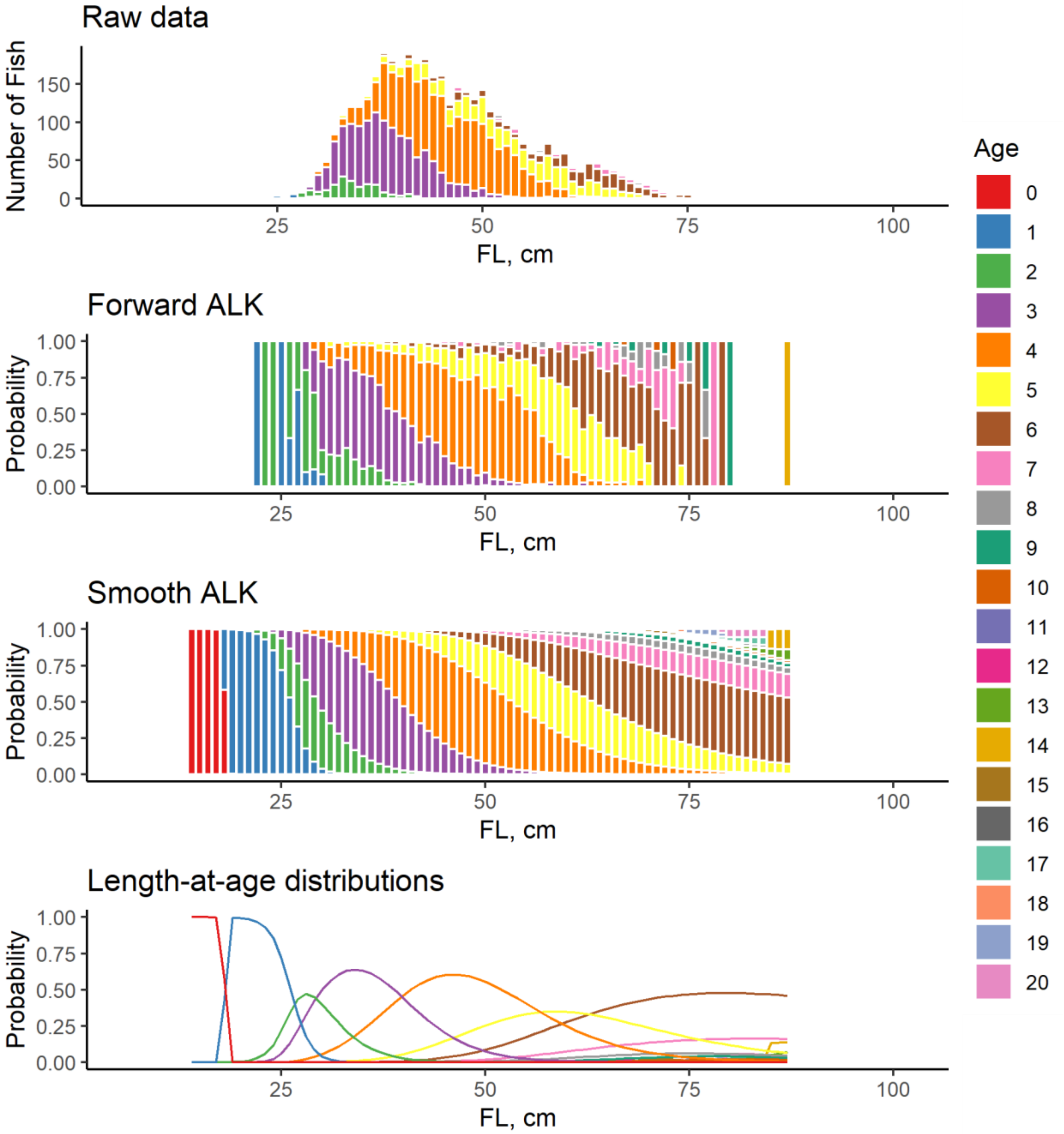

Figure 47. Age data and derived ALKs for 2010 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

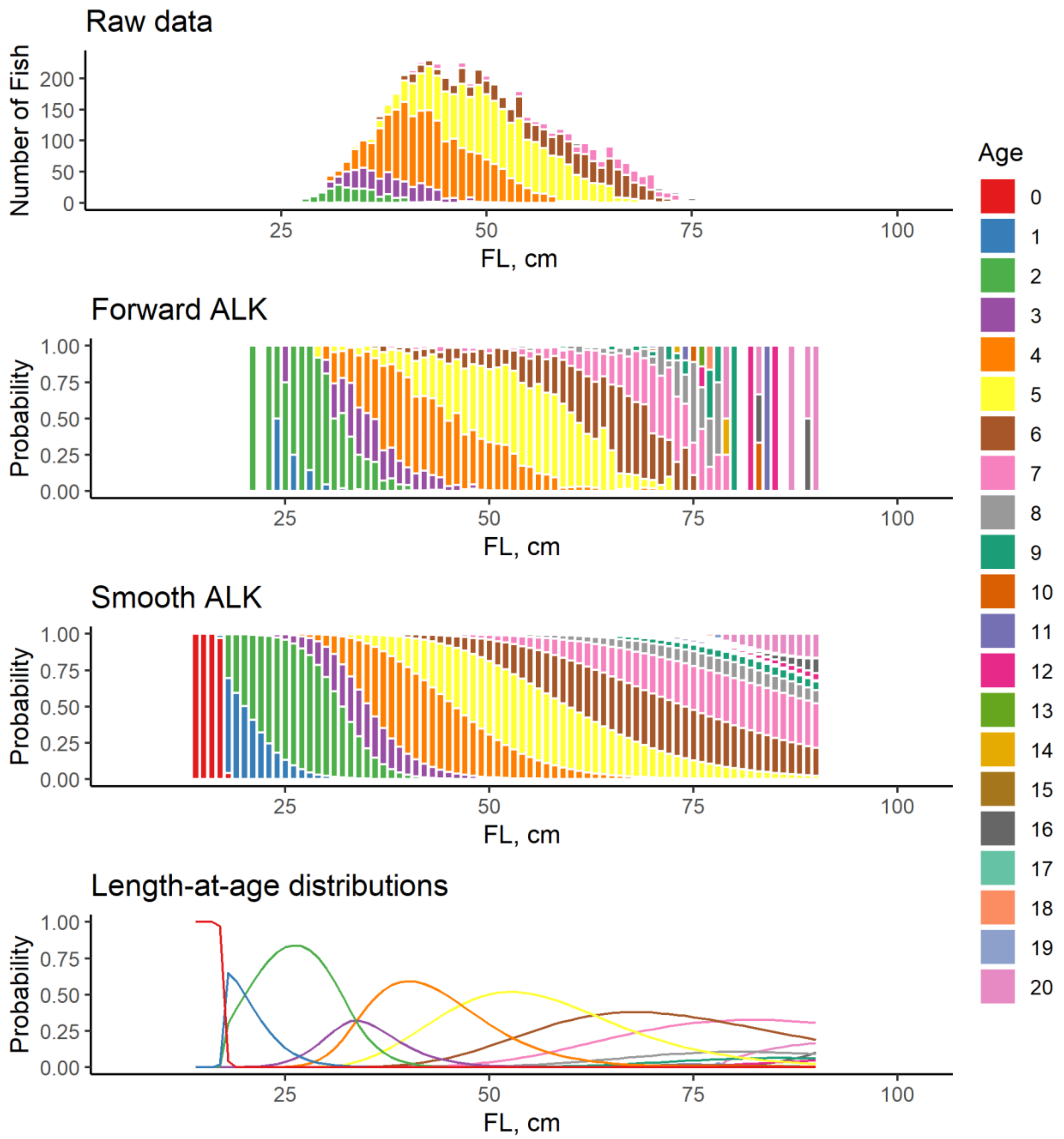

Figure 48. Age data and derived ALKs for 2011 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

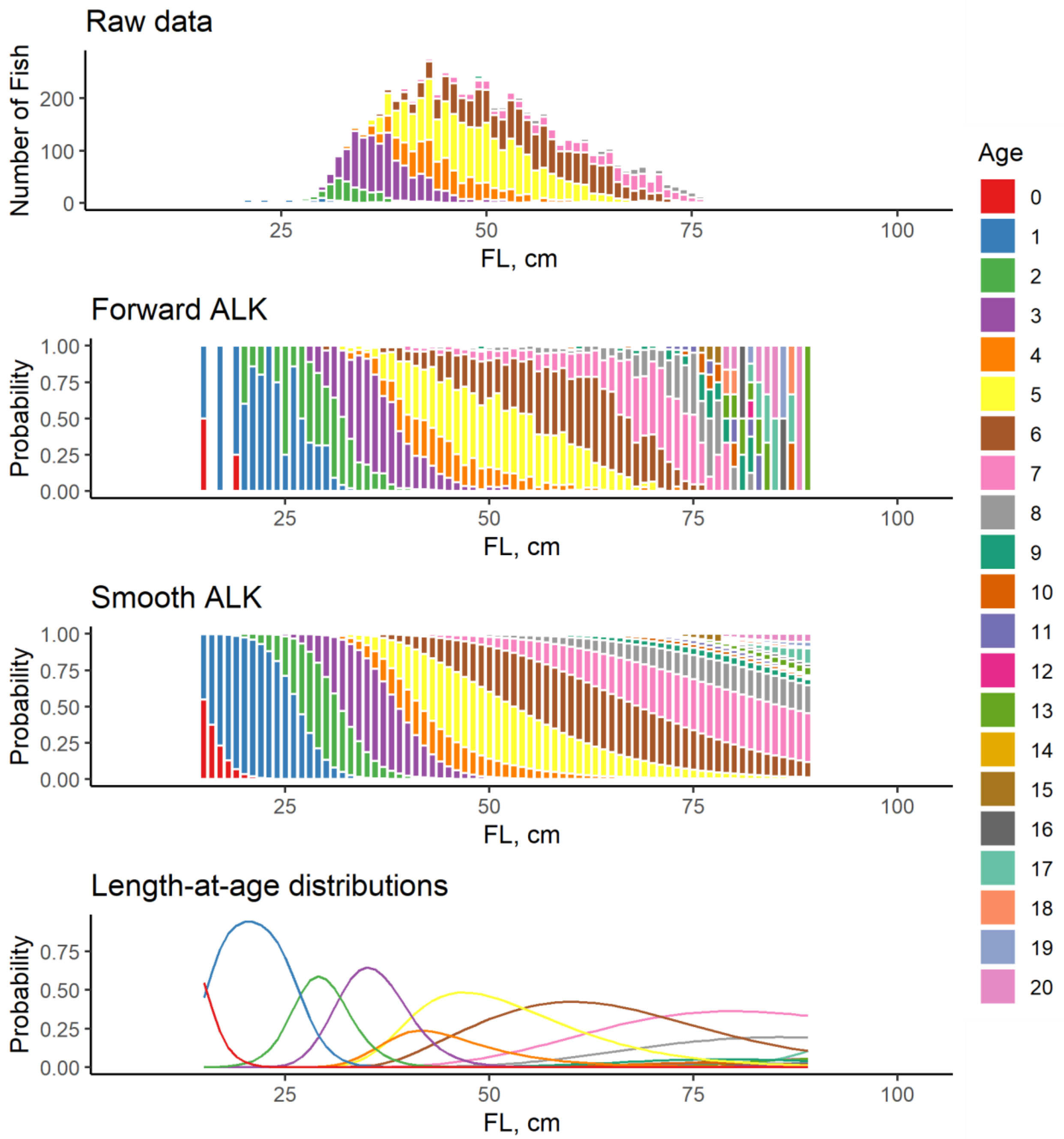

Figure 49. Age data and derived ALKs for 2012 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

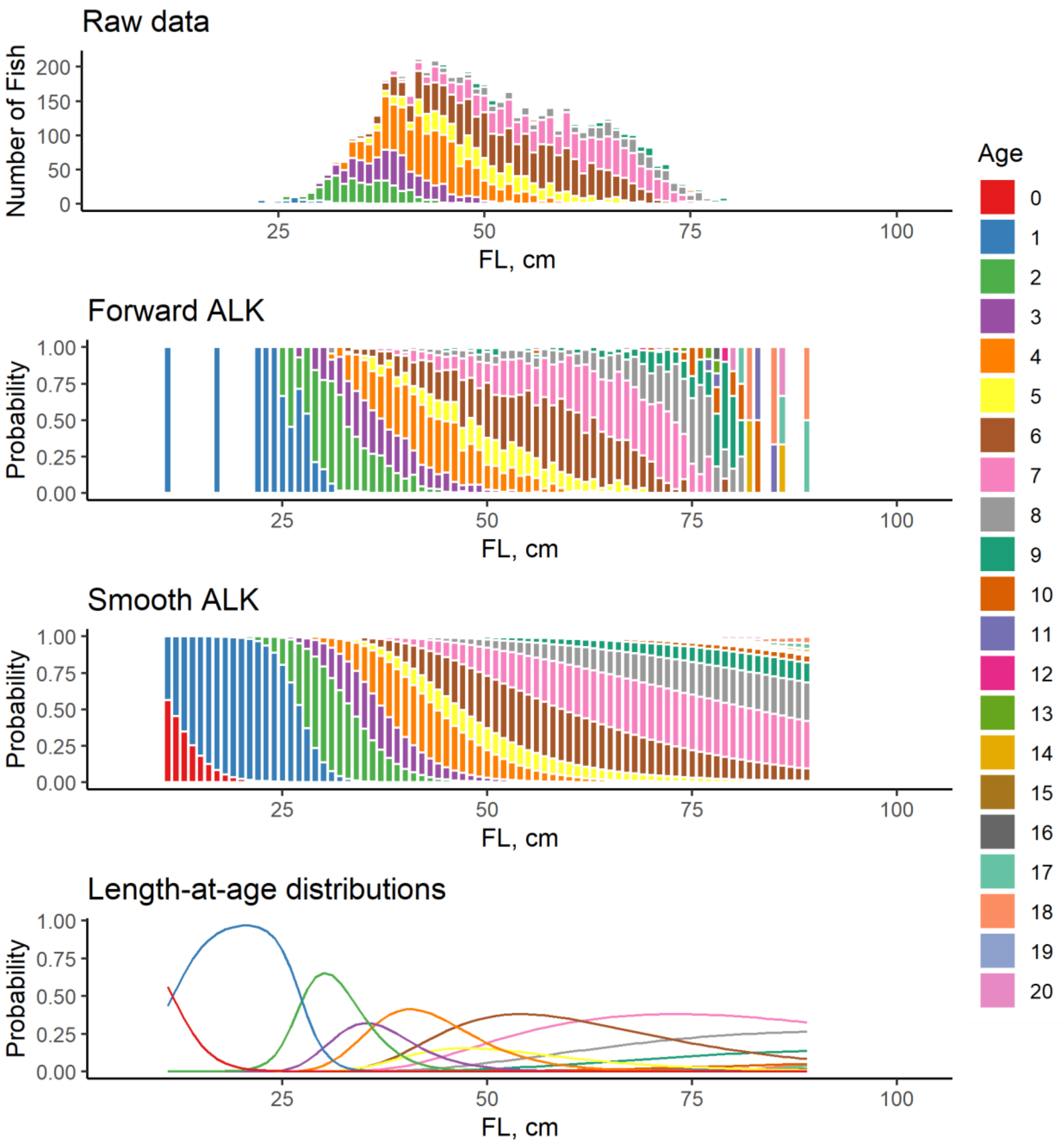

Figure 50. Age data and derived ALKs for 2013 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

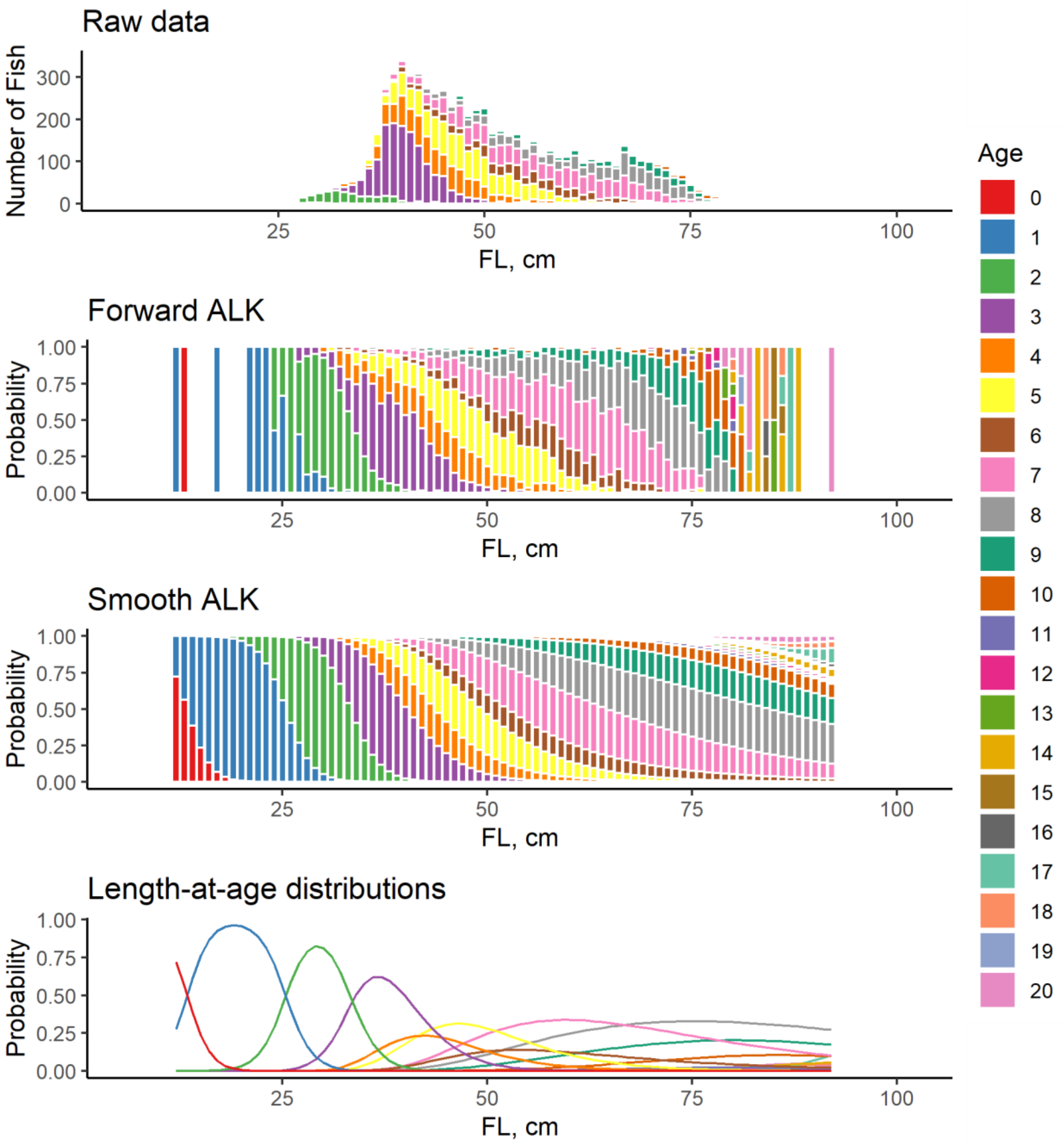

Figure 51. Age data and derived ALKs for 2014 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

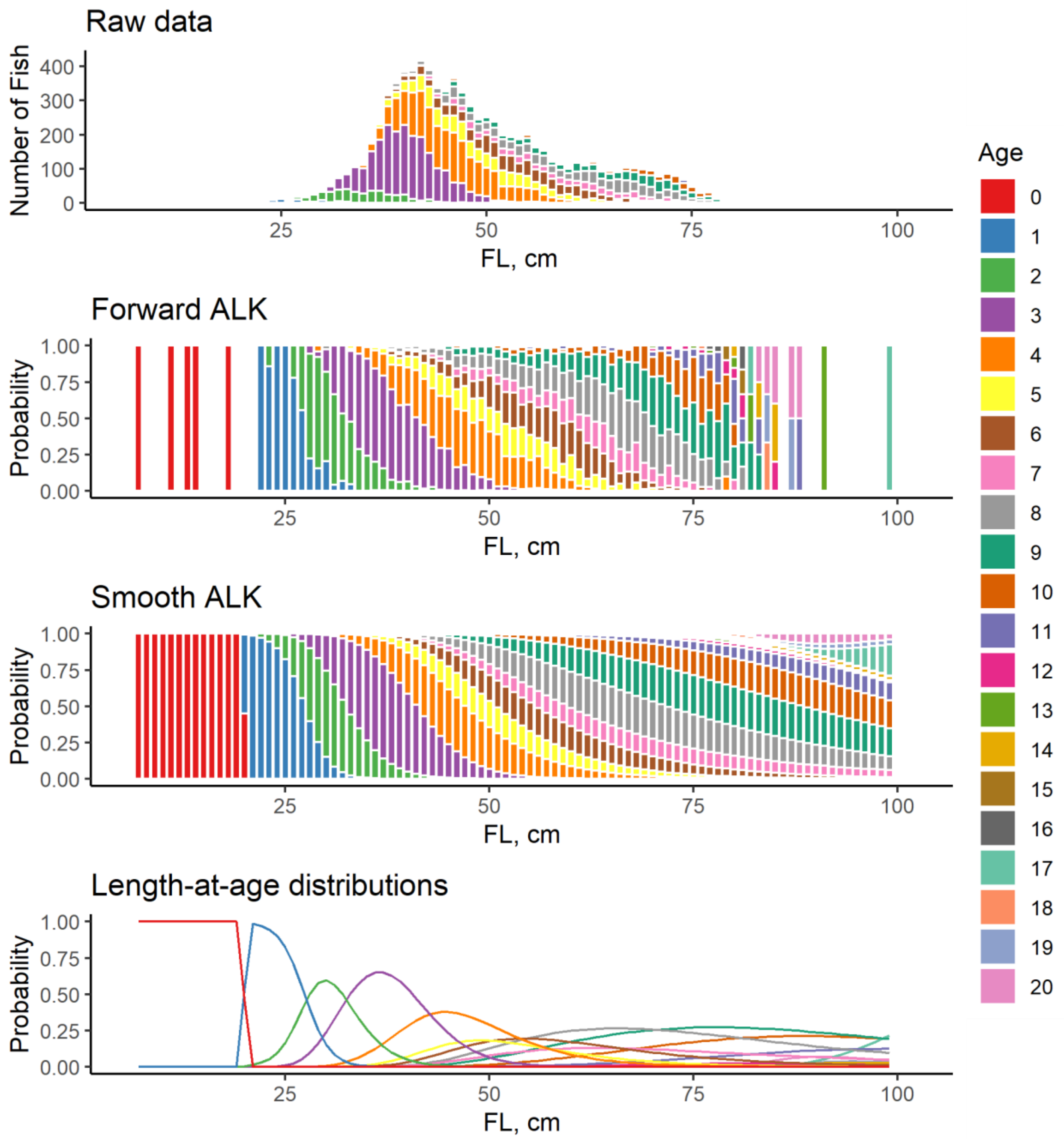

Figure 52. Age data and derived ALKs for 2015 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

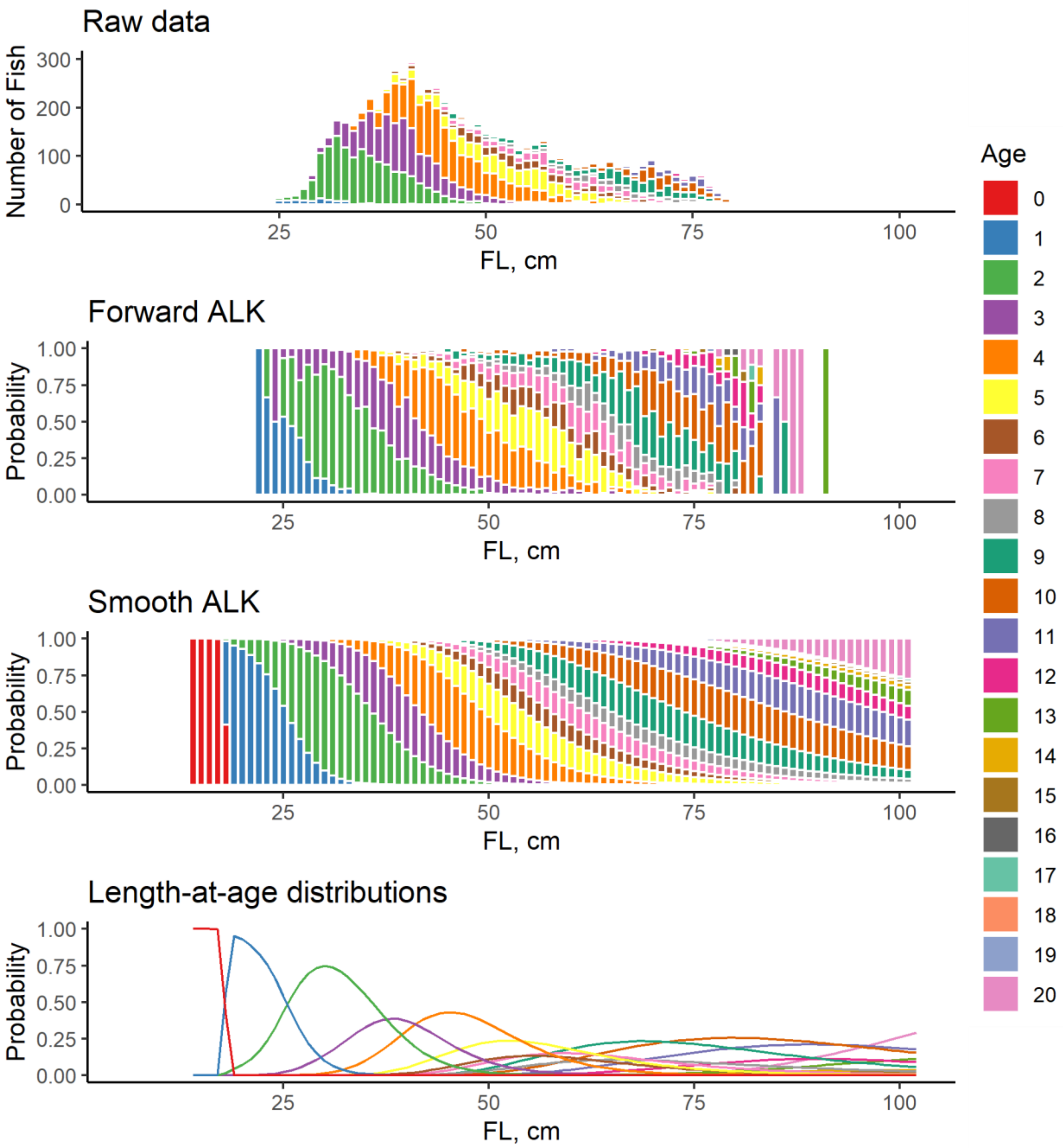

Figure 53. Age data and derived ALKs for 2016 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

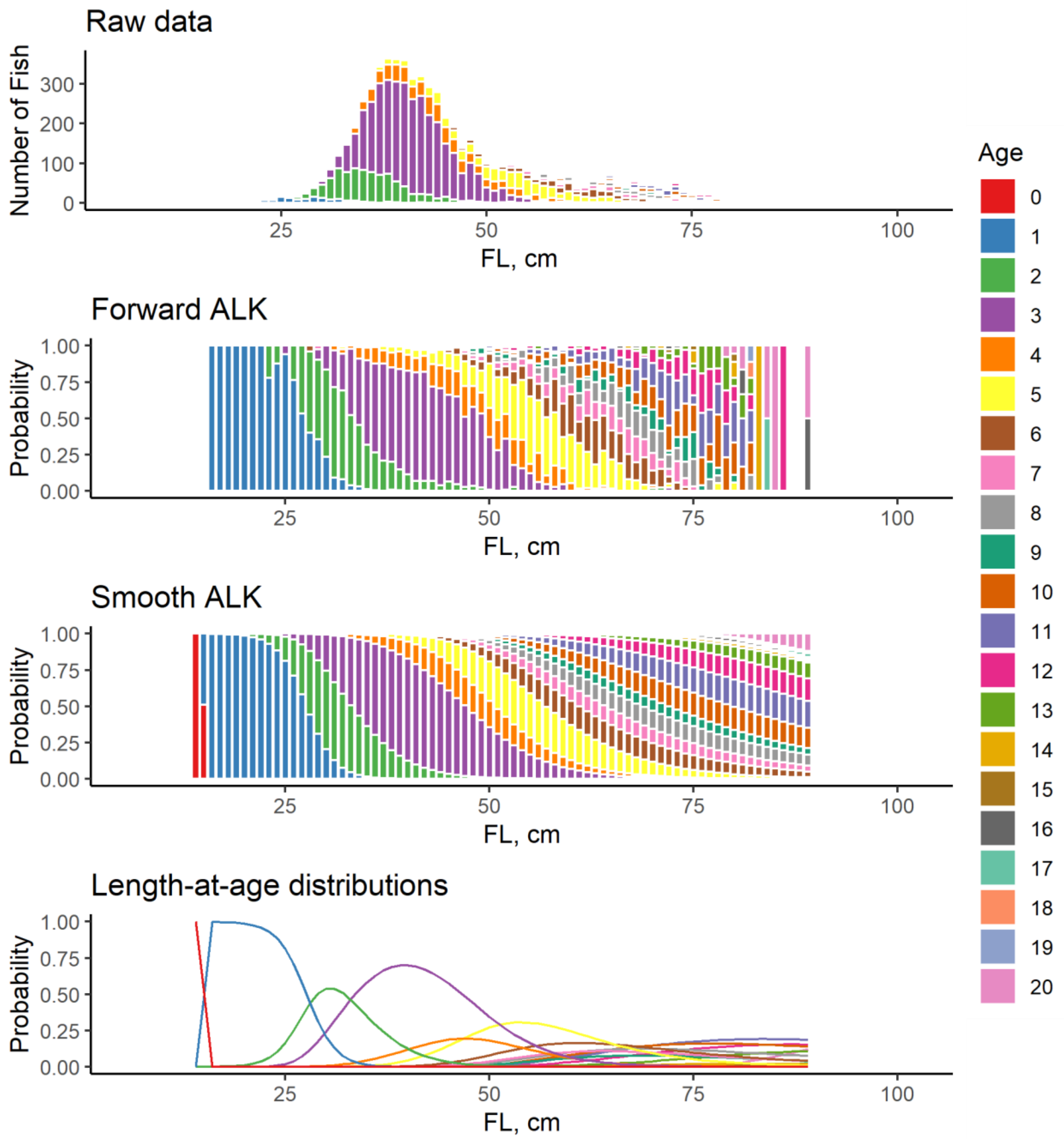

Figure 54. Age data and derived ALKs for 2017 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

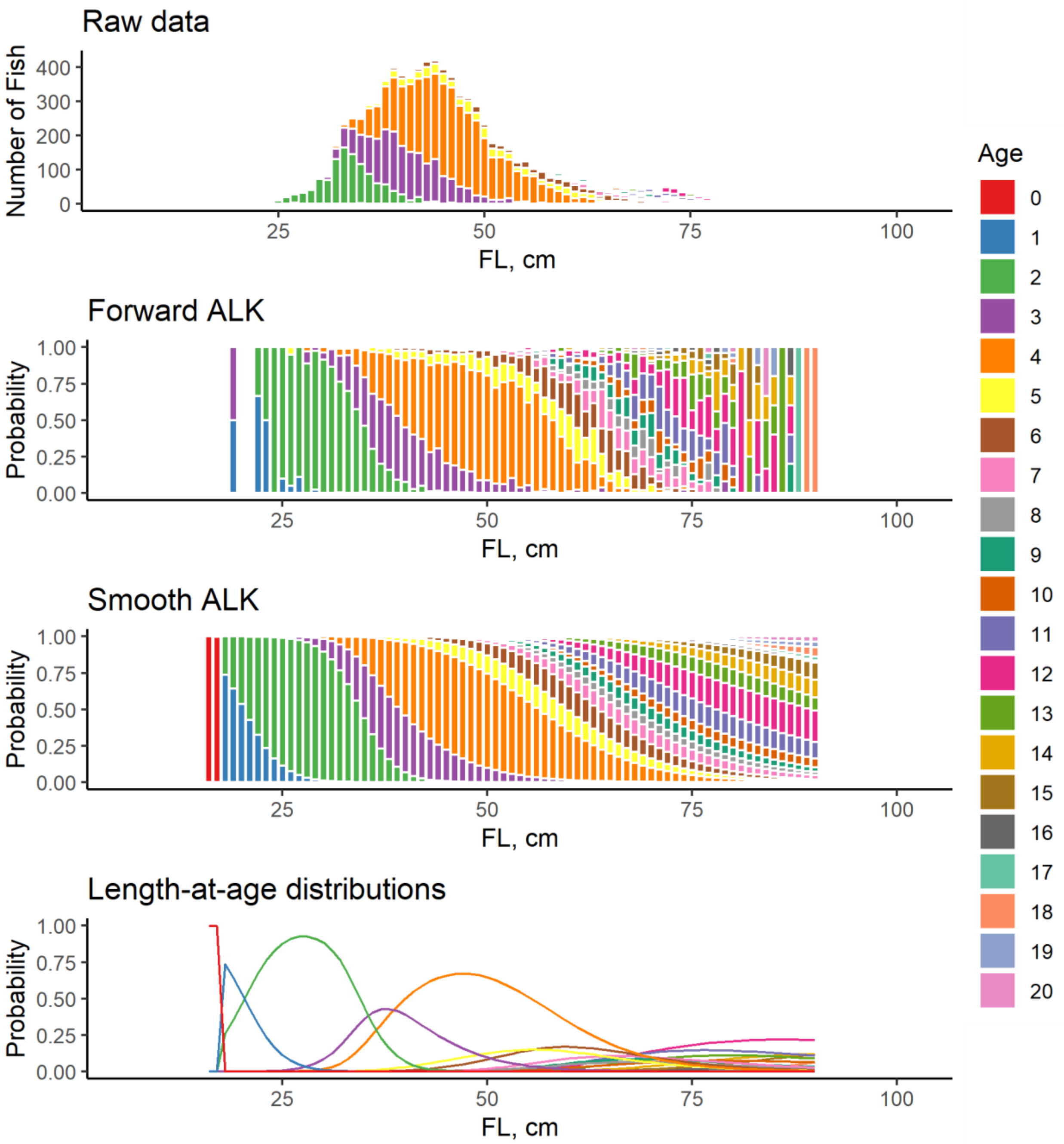

Figure 55. Age data and derived ALKs for 2018 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

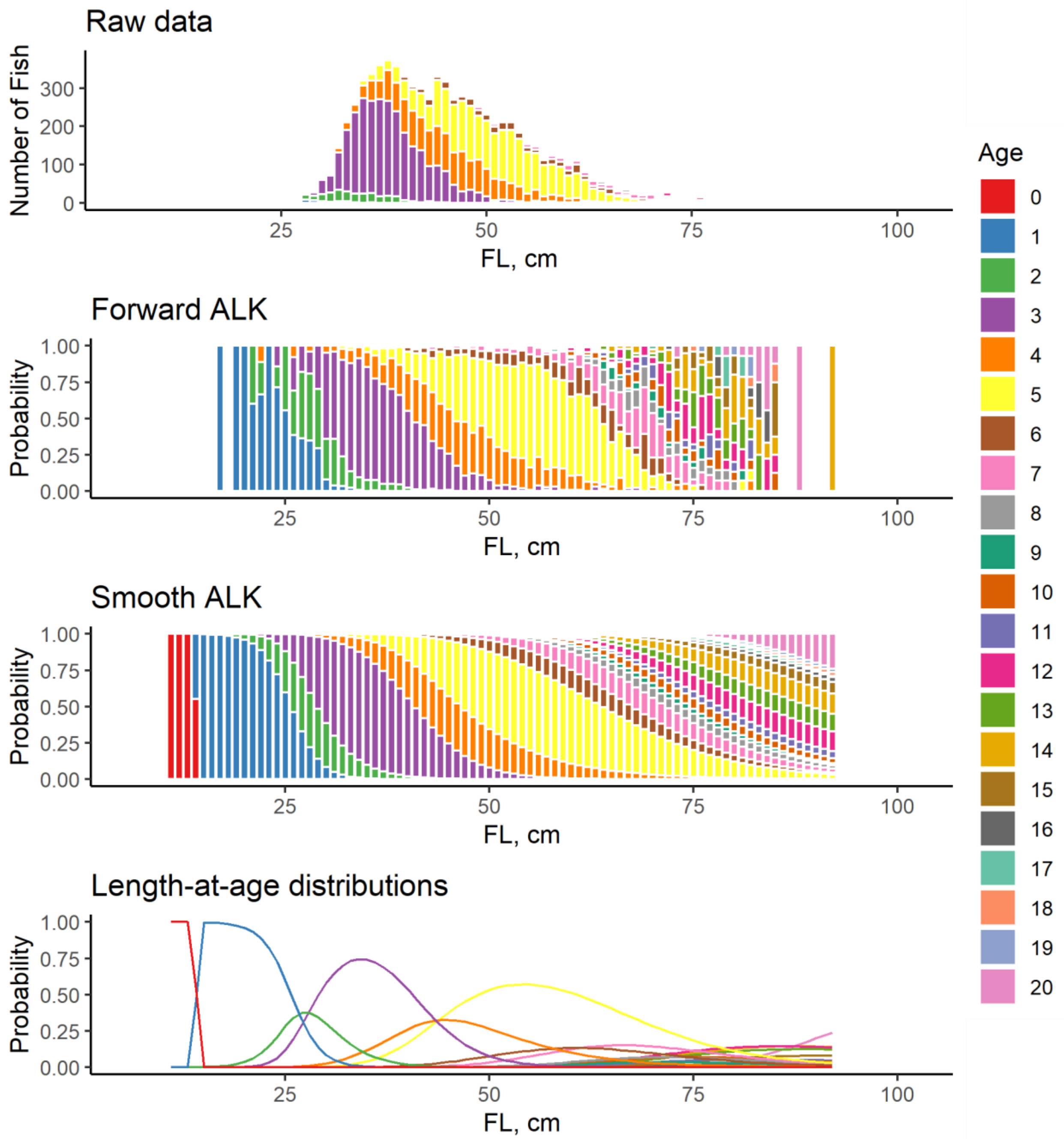

Figure 56. Age data and derived ALKs for 2019 in the C region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

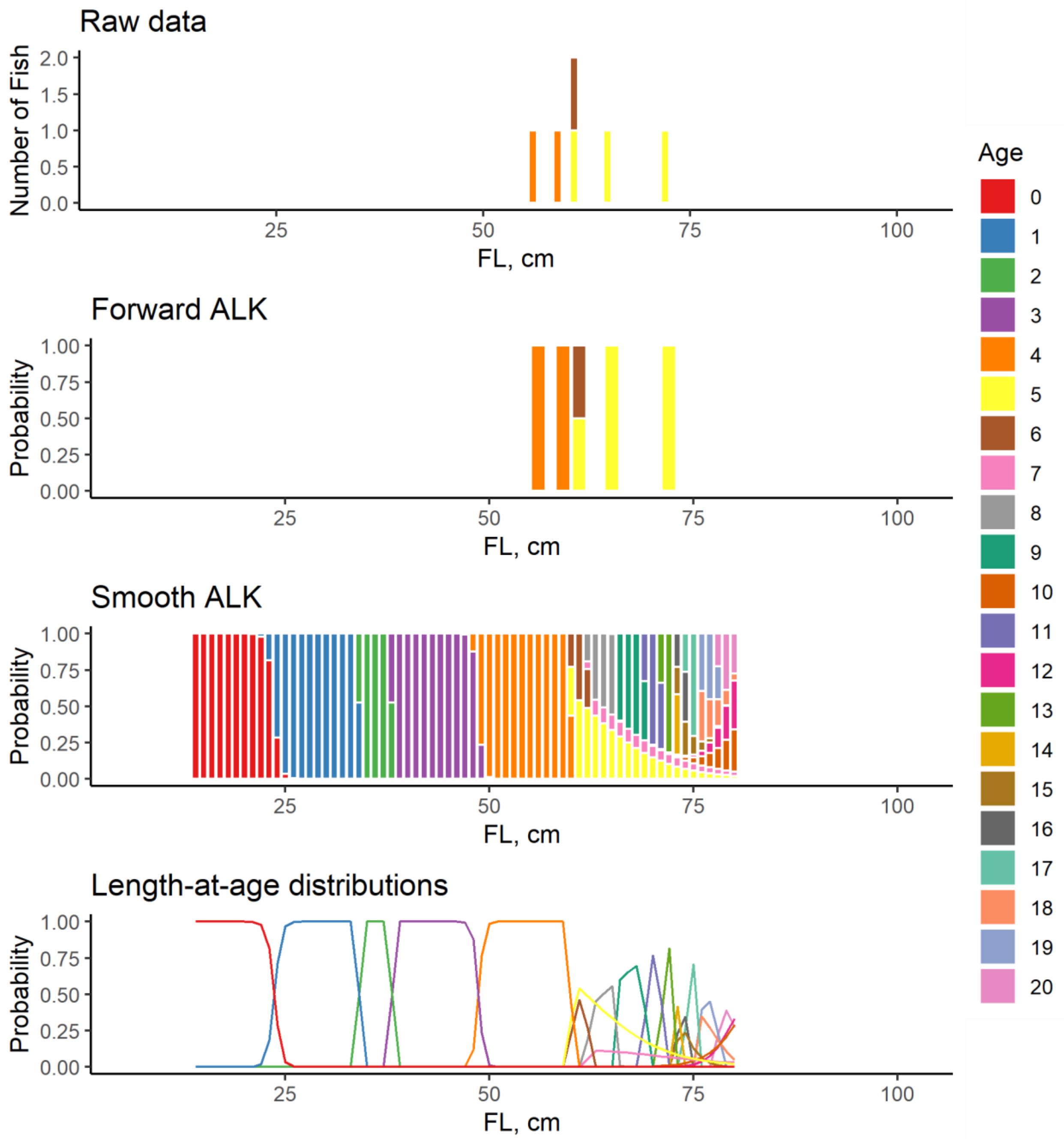

Figure 57. Age data and derived ALKs for 1996 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

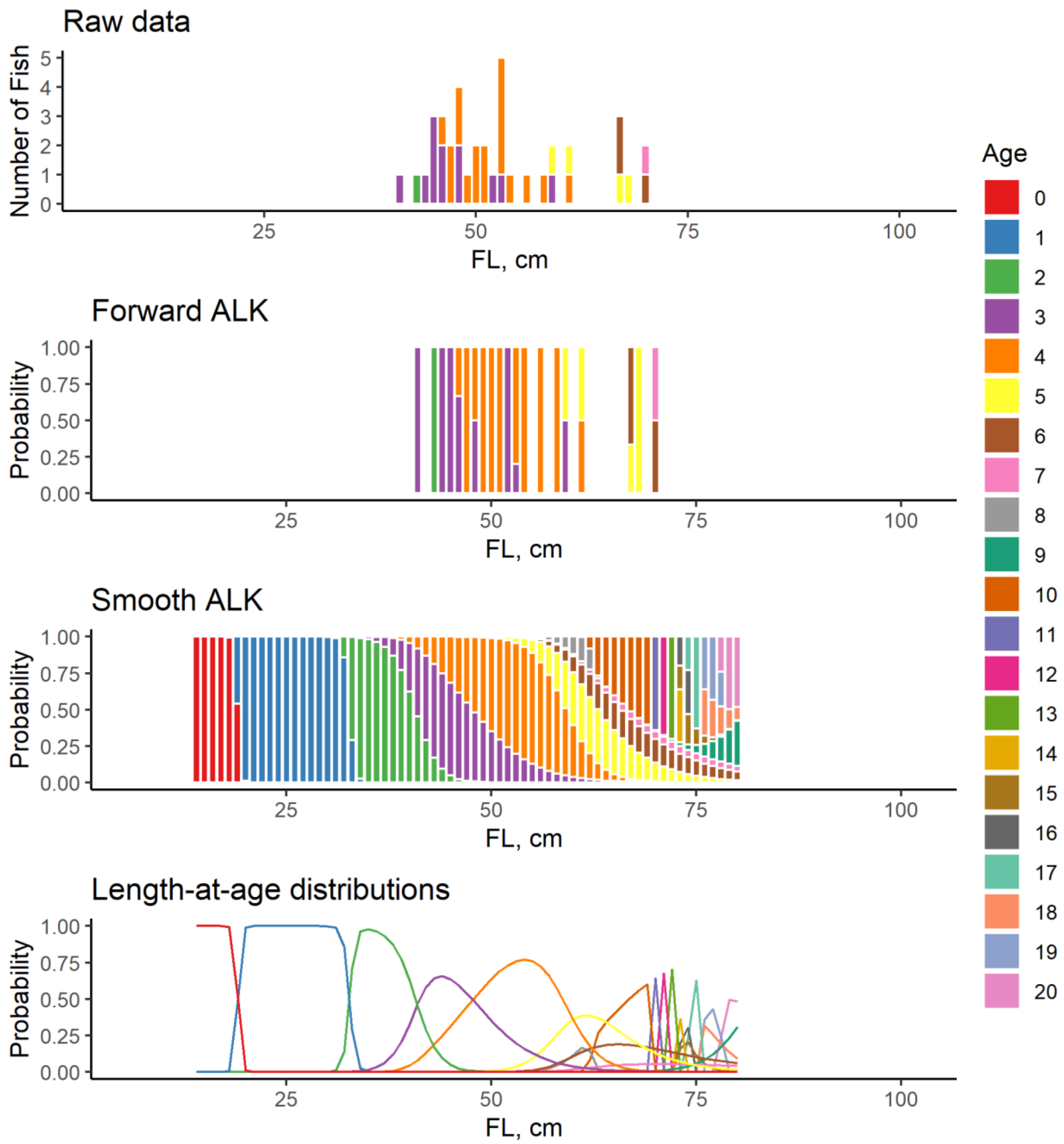

Figure 58. Age data and derived ALKs for 1997 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

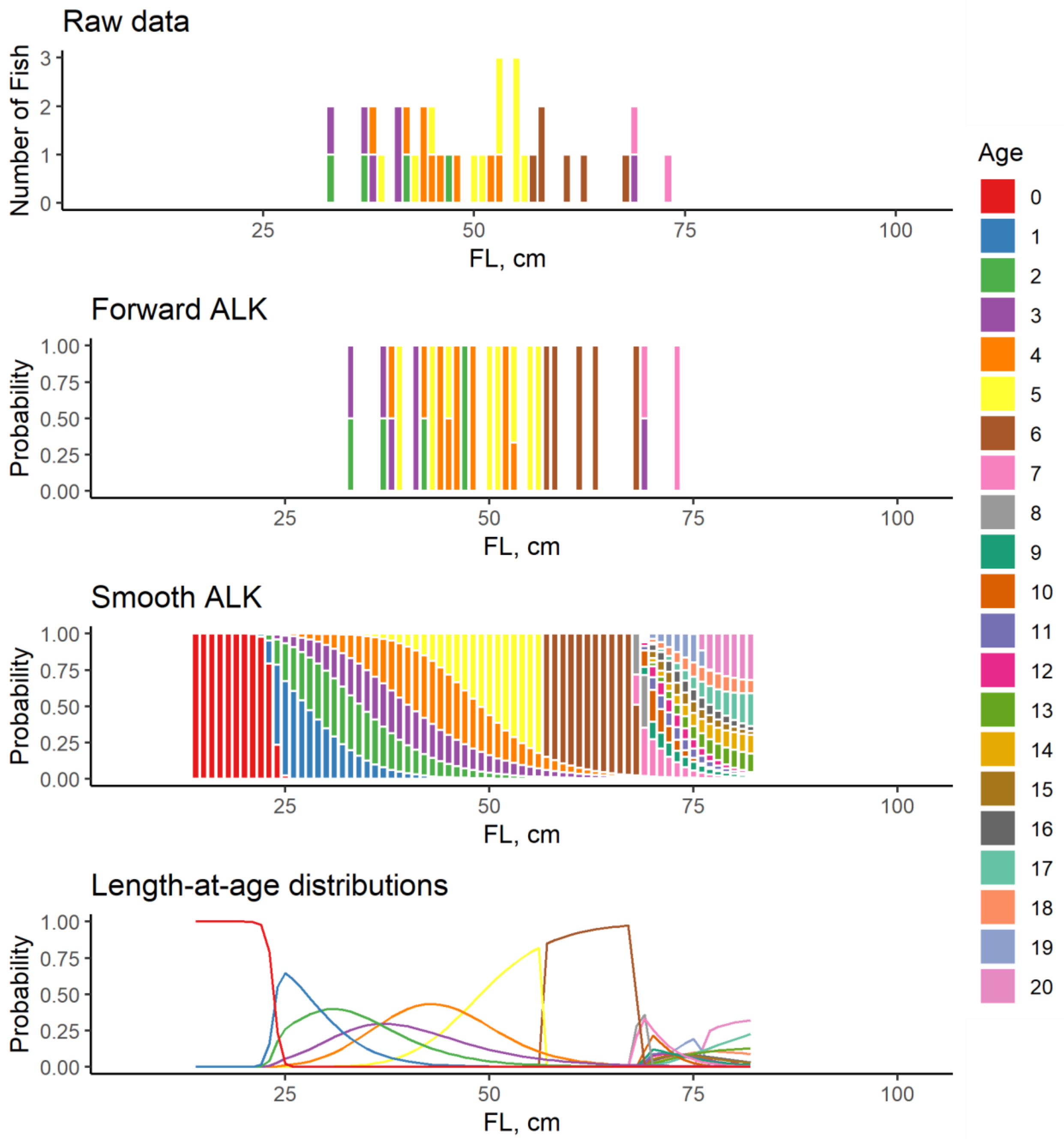

Figure 59. Age data and derived ALKs for 1998 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

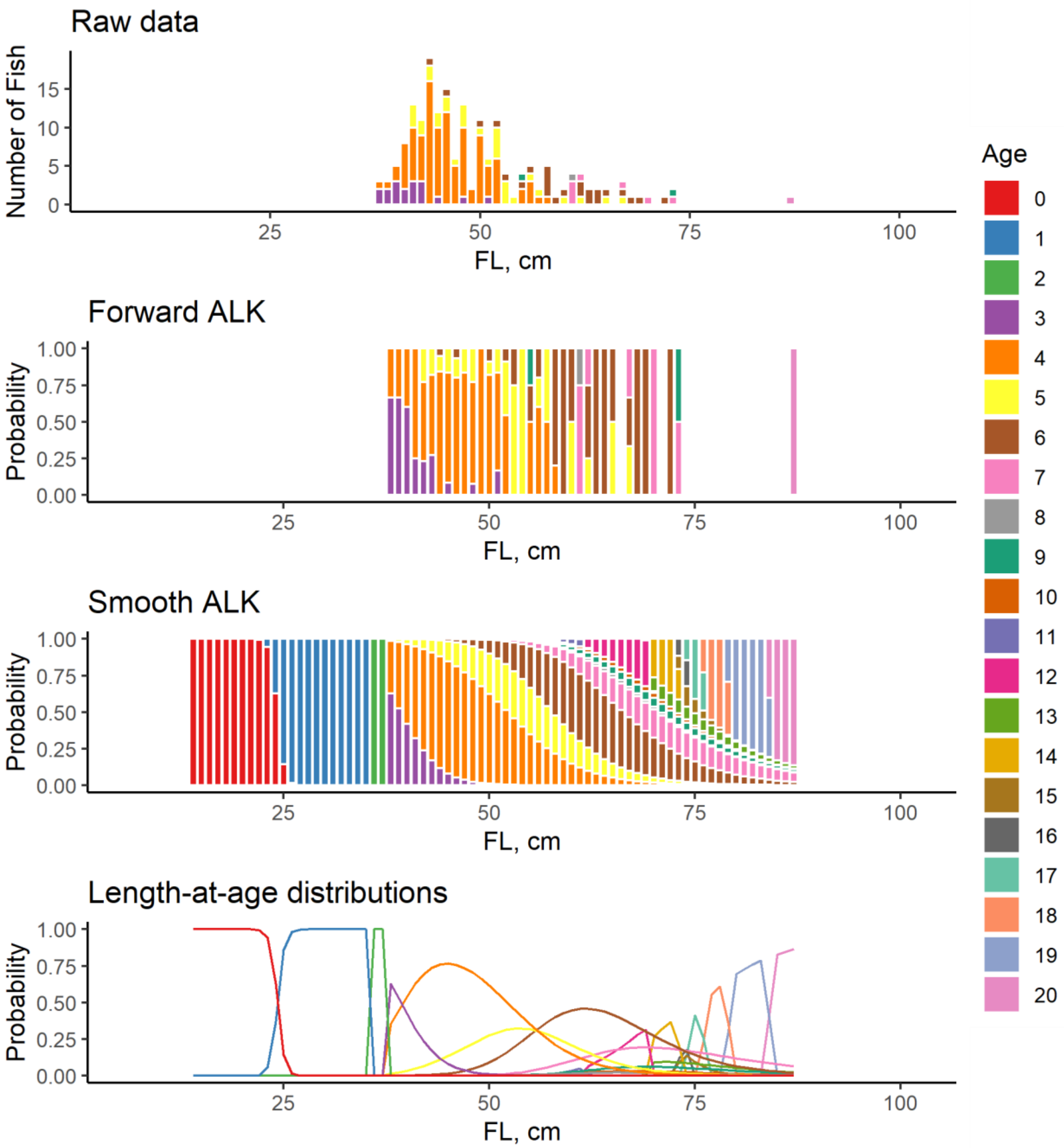

Figure 60. Age data and derived ALKs for 1999 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

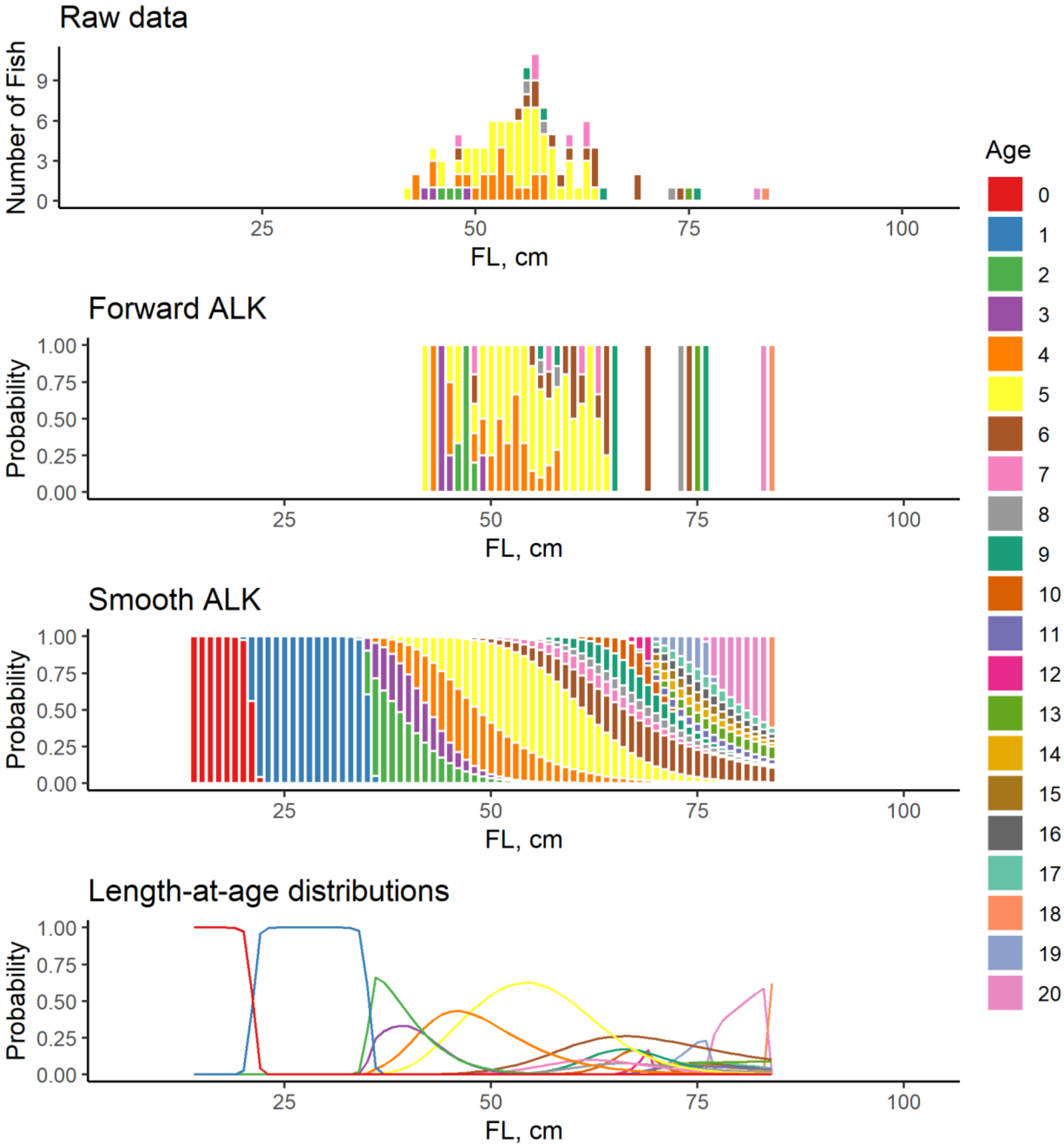

Figure 61. Age data and derived ALKs for 2000 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

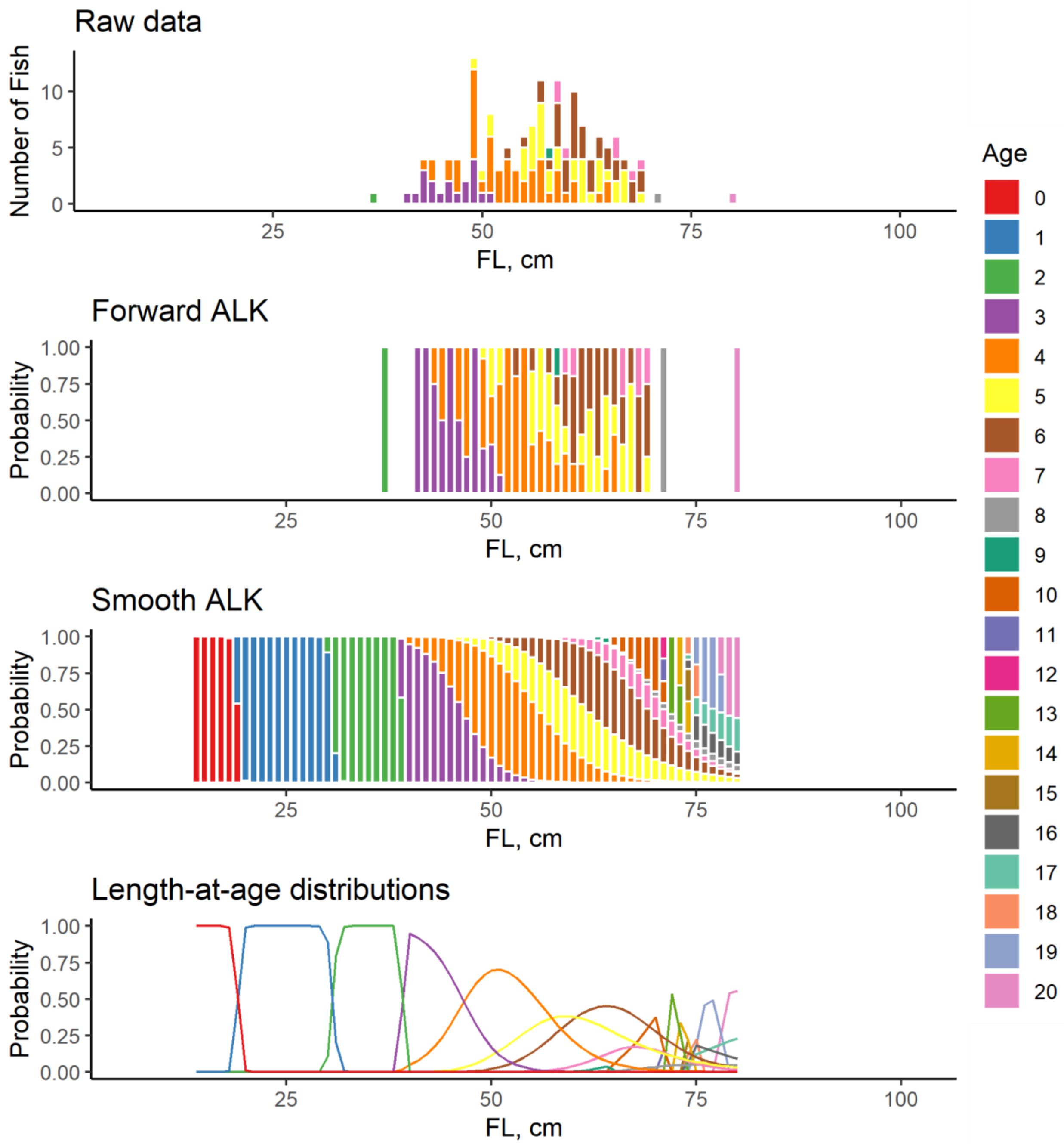

Figure 62. Age data and derived ALKs for 2001 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

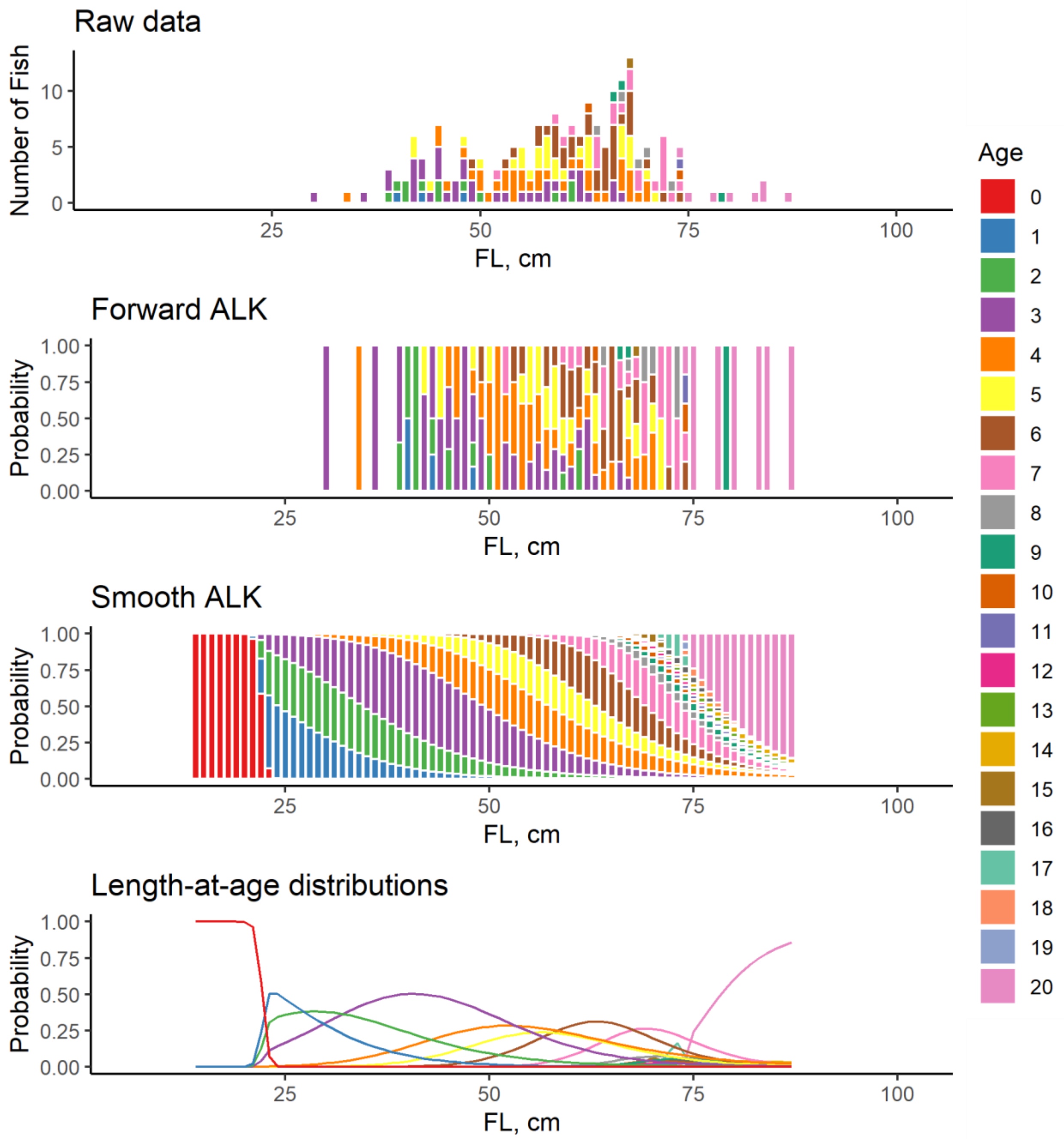

Figure 63. Age data and derived ALKs for 2002 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

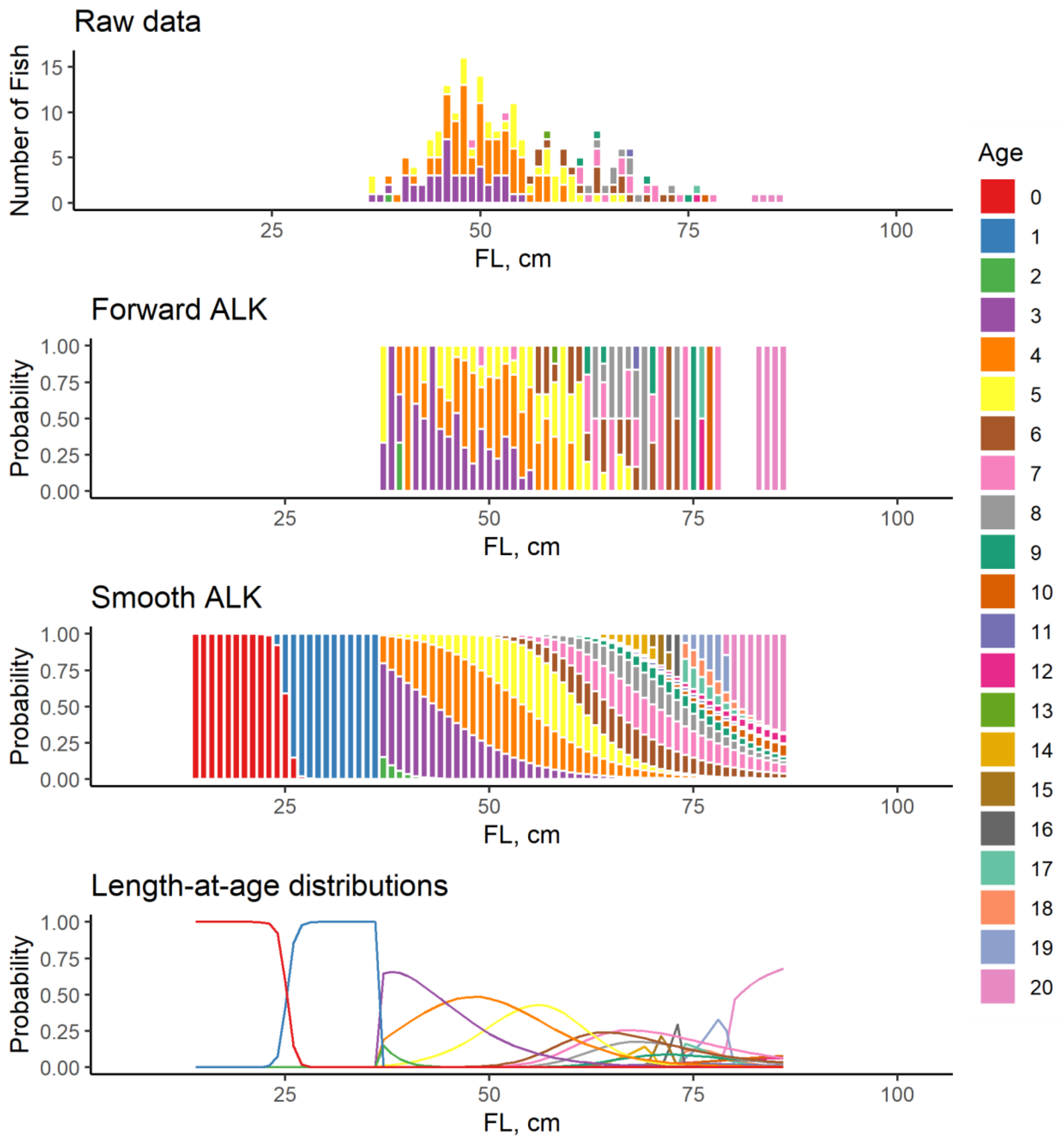

Figure 64. Age data and derived ALKs for 2003 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

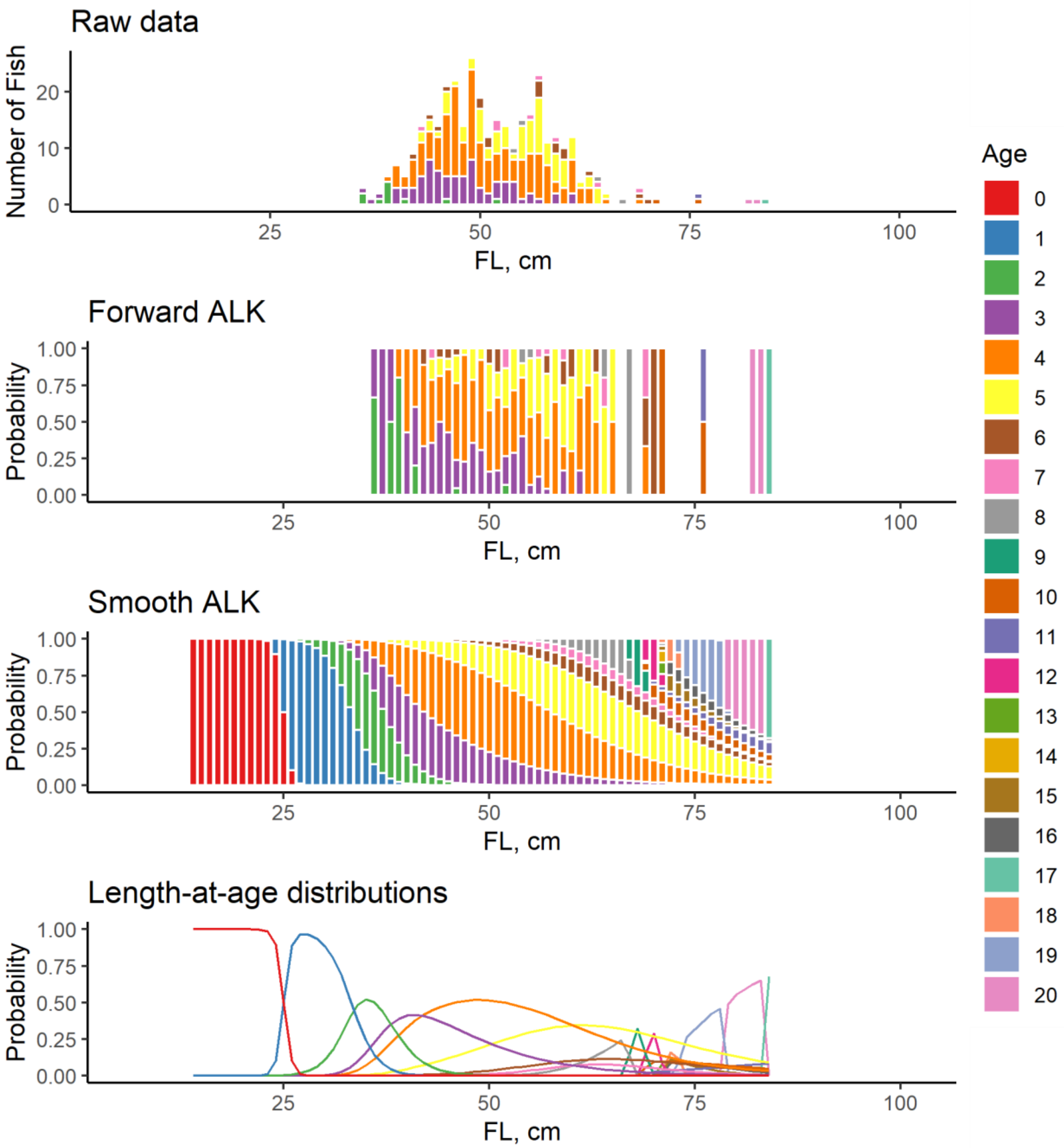

Figure 65. Age data and derived ALKs for 2004 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

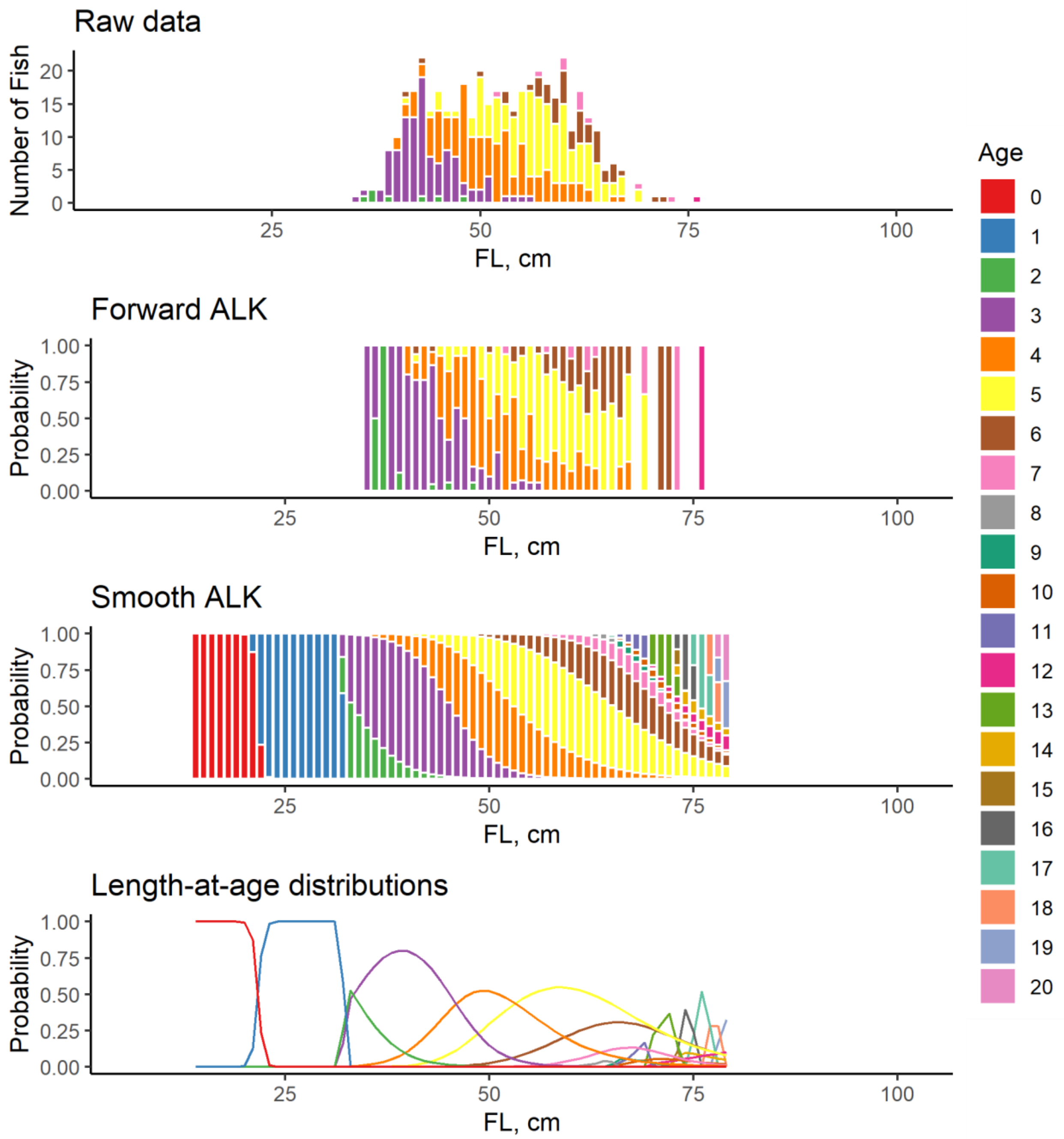

Figure 66. Age data and derived ALKs for 2005 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

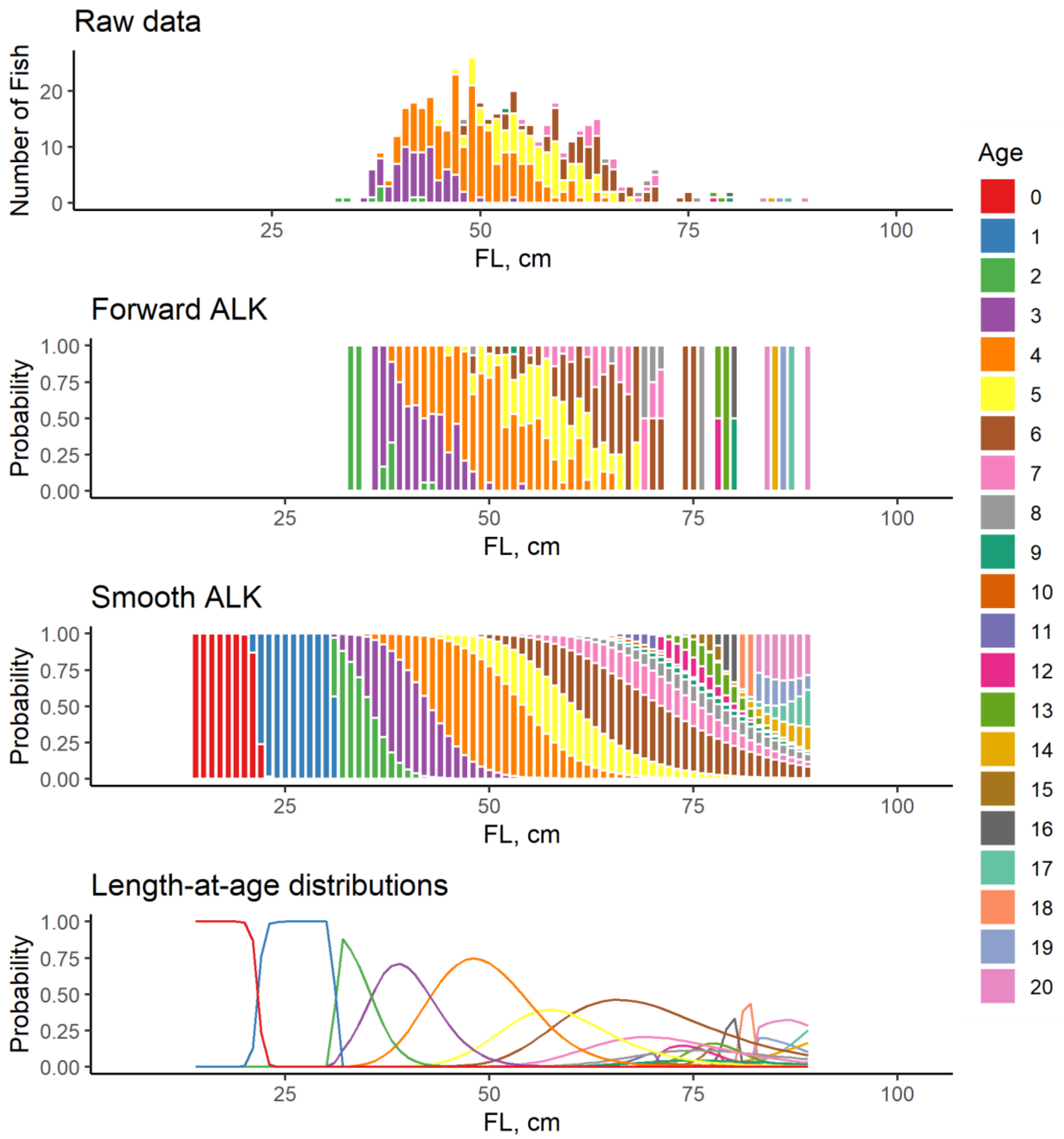

Figure 67. Age data and derived ALKs for 2006 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

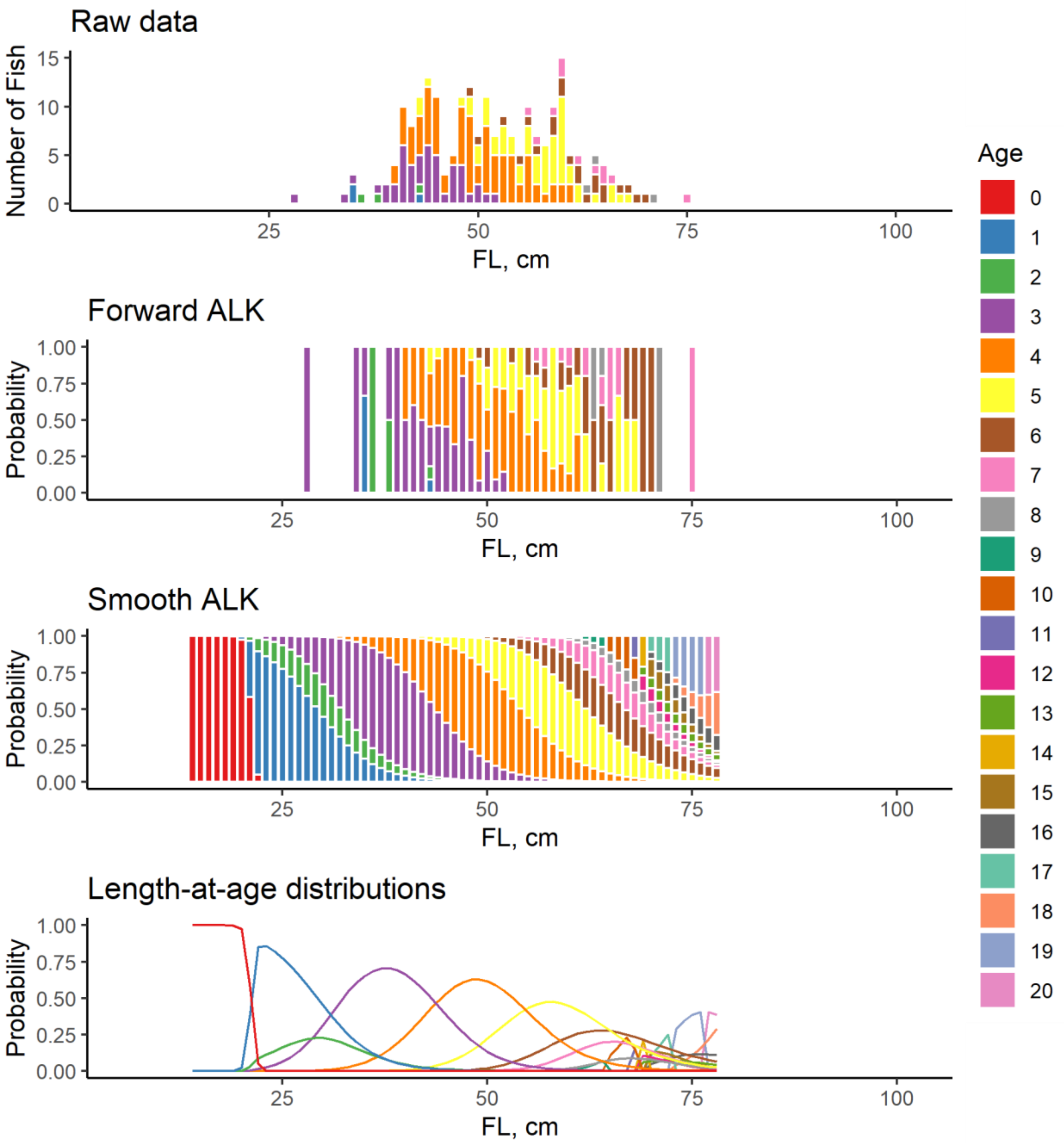

Figure 68. Age data and derived ALKs for 2007 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

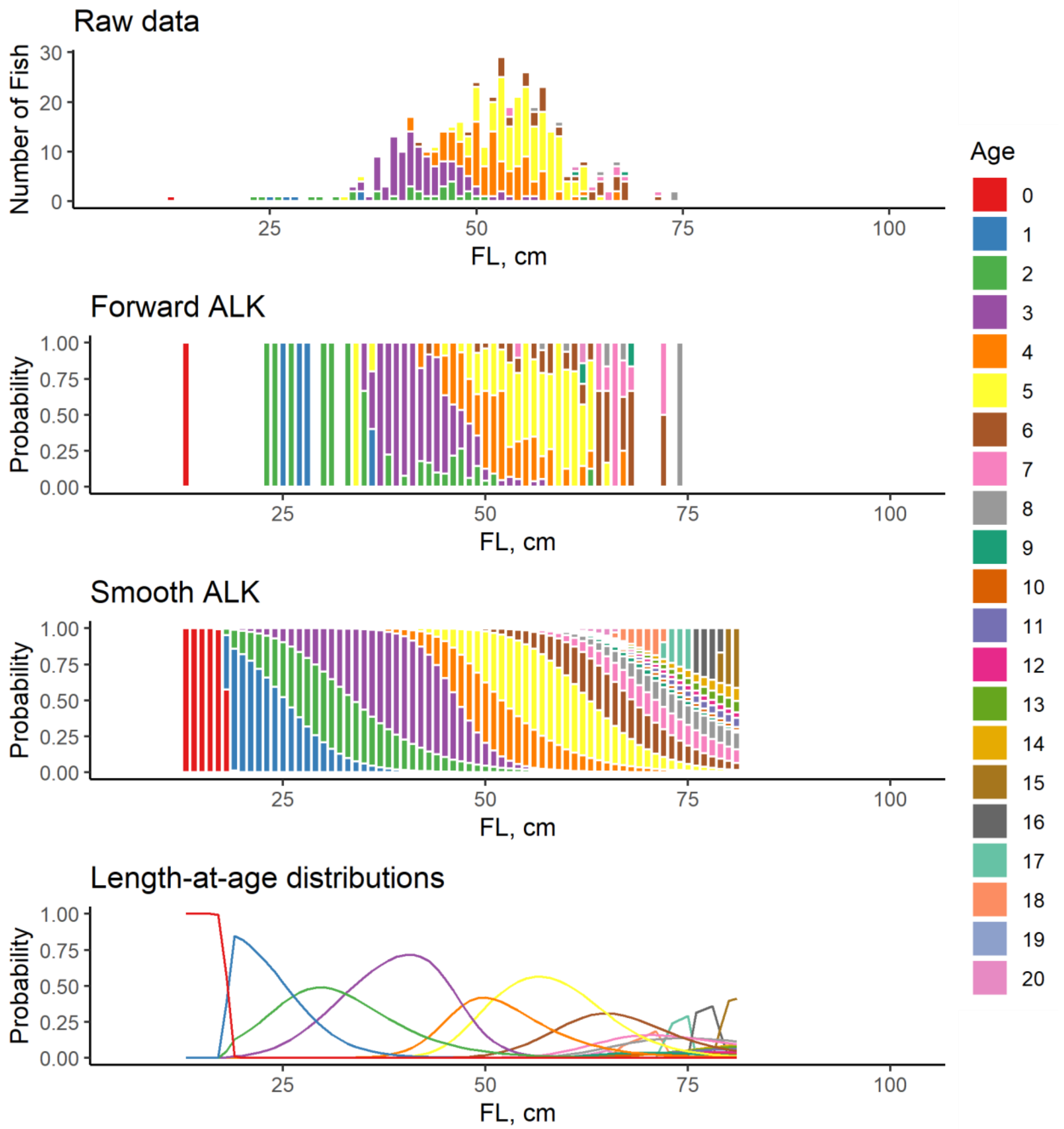

Figure 69. Age data and derived ALKs for 2008 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

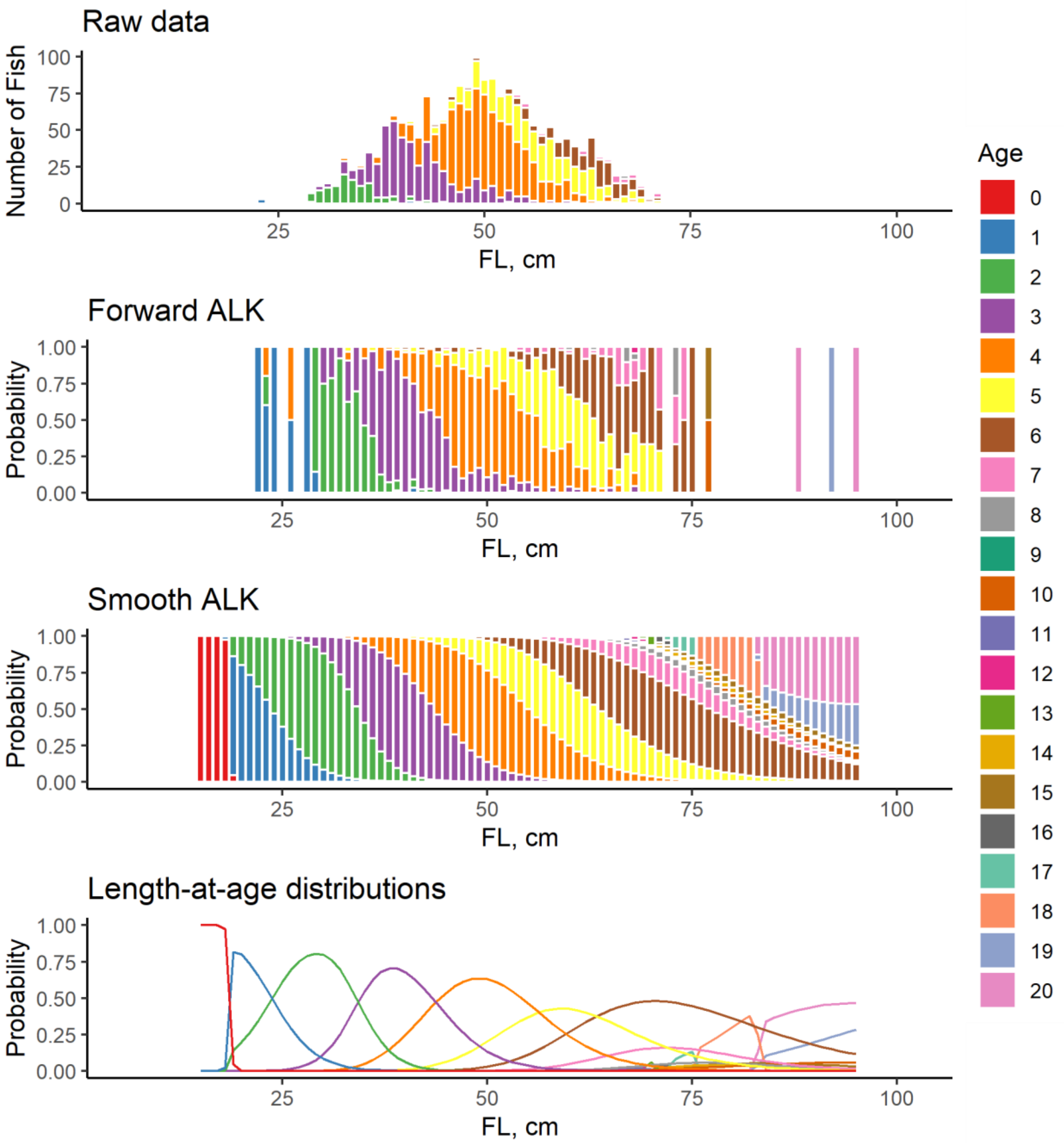

Figure 70. Age data and derived ALKs for 2009 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

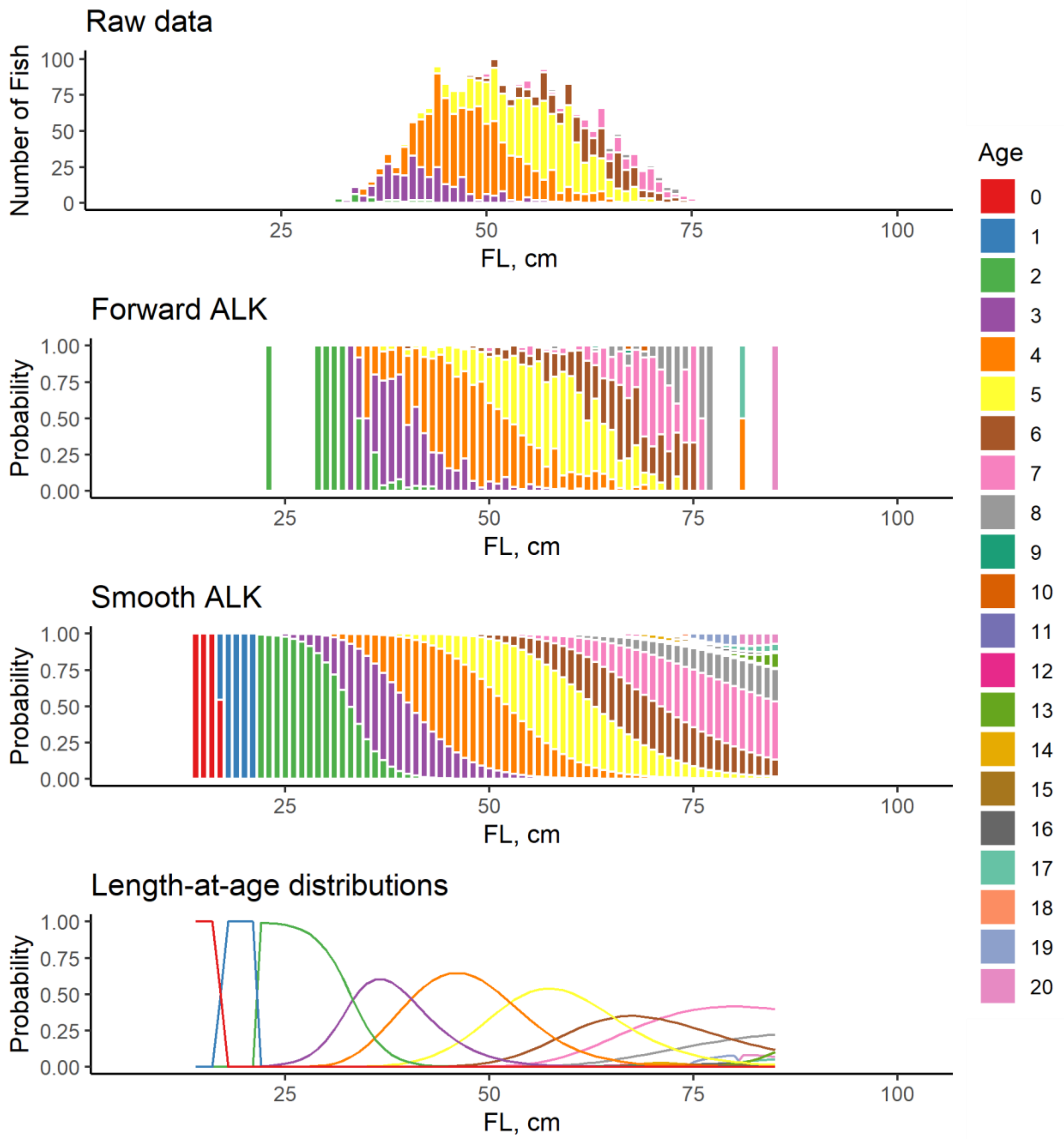

Figure 71. Age data and derived ALKs for 2010 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

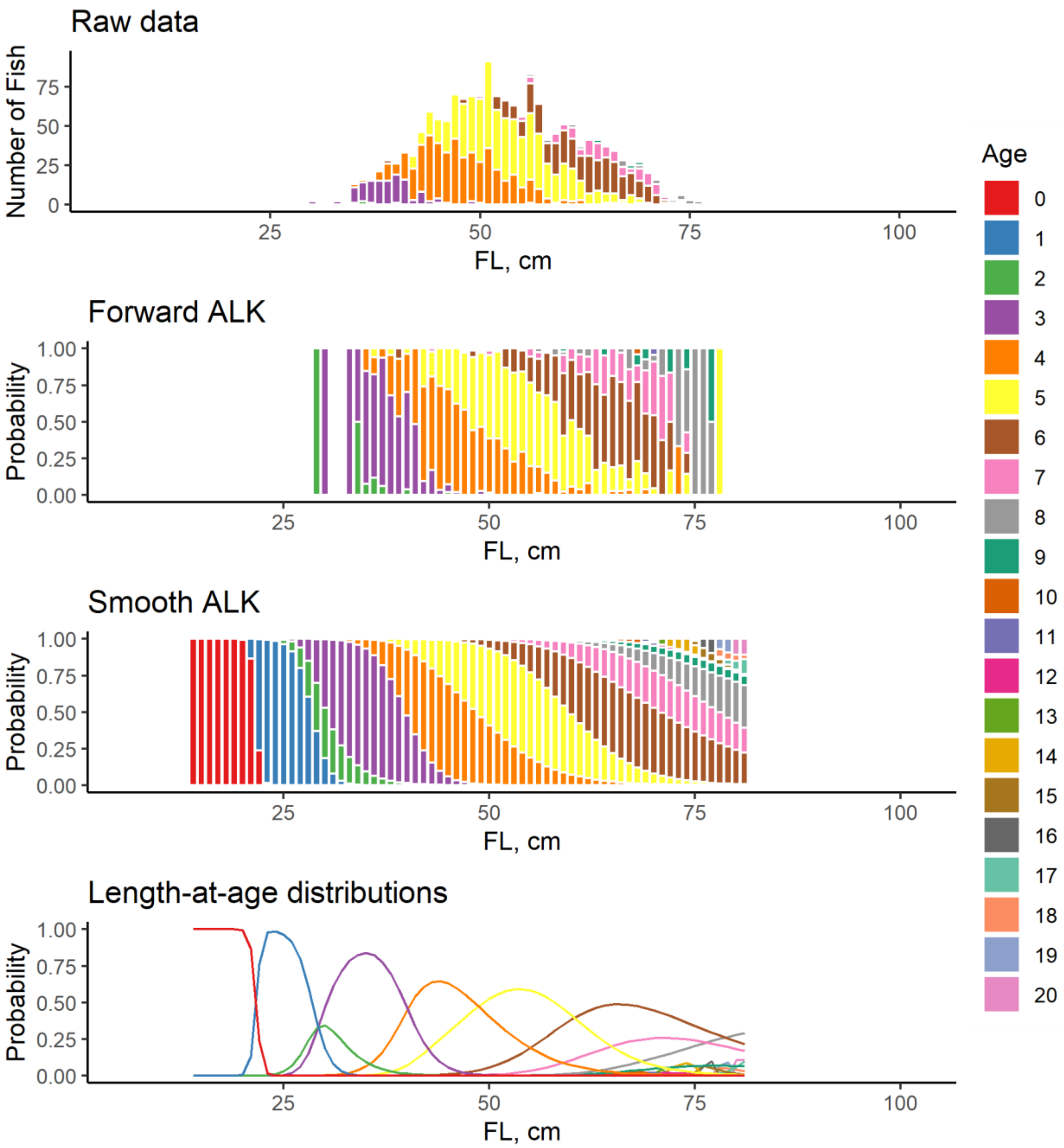

Figure 72. Age data and derived ALKs for 2011 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

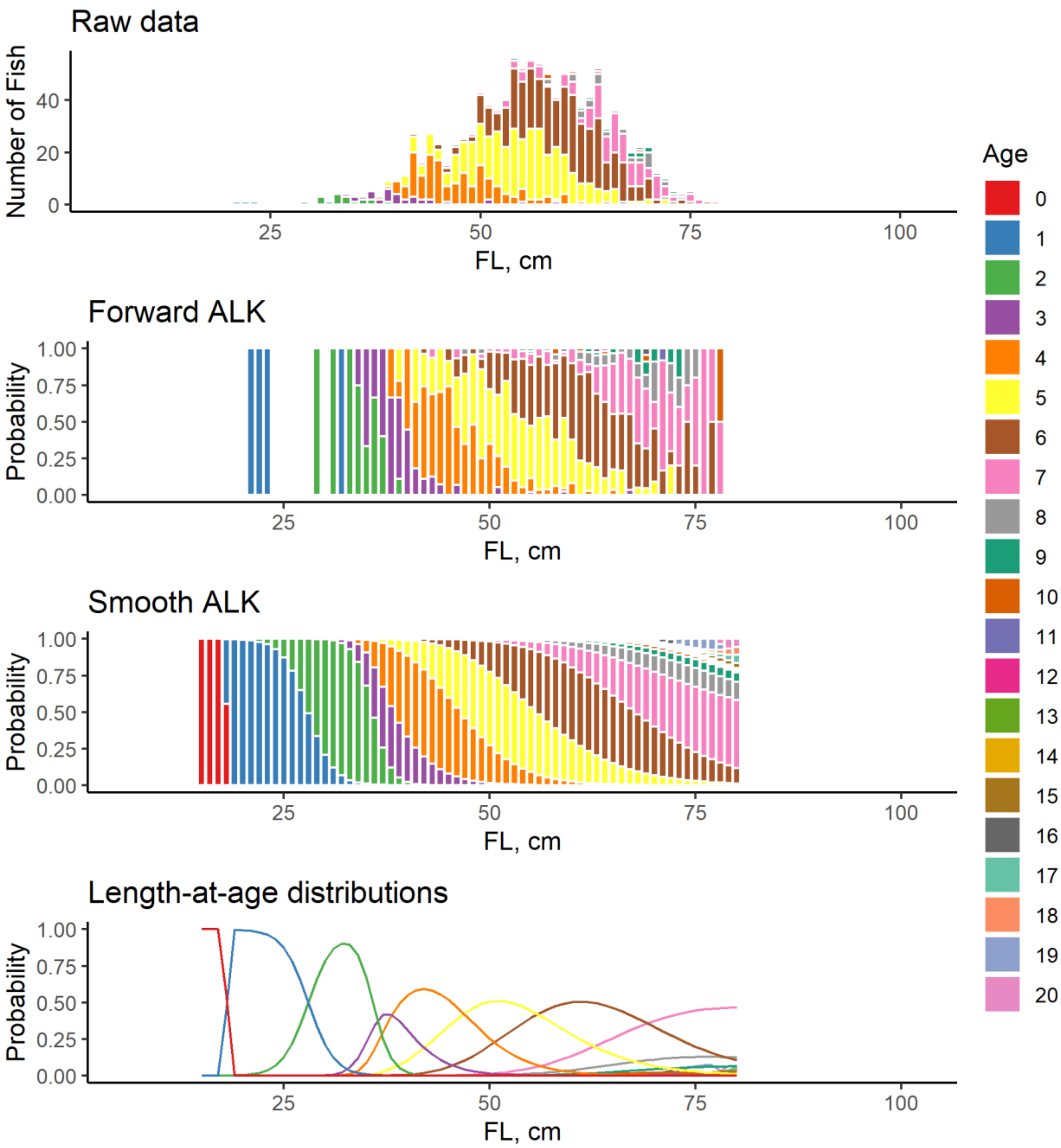

Figure 73. Age data and derived ALKs for 2012 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

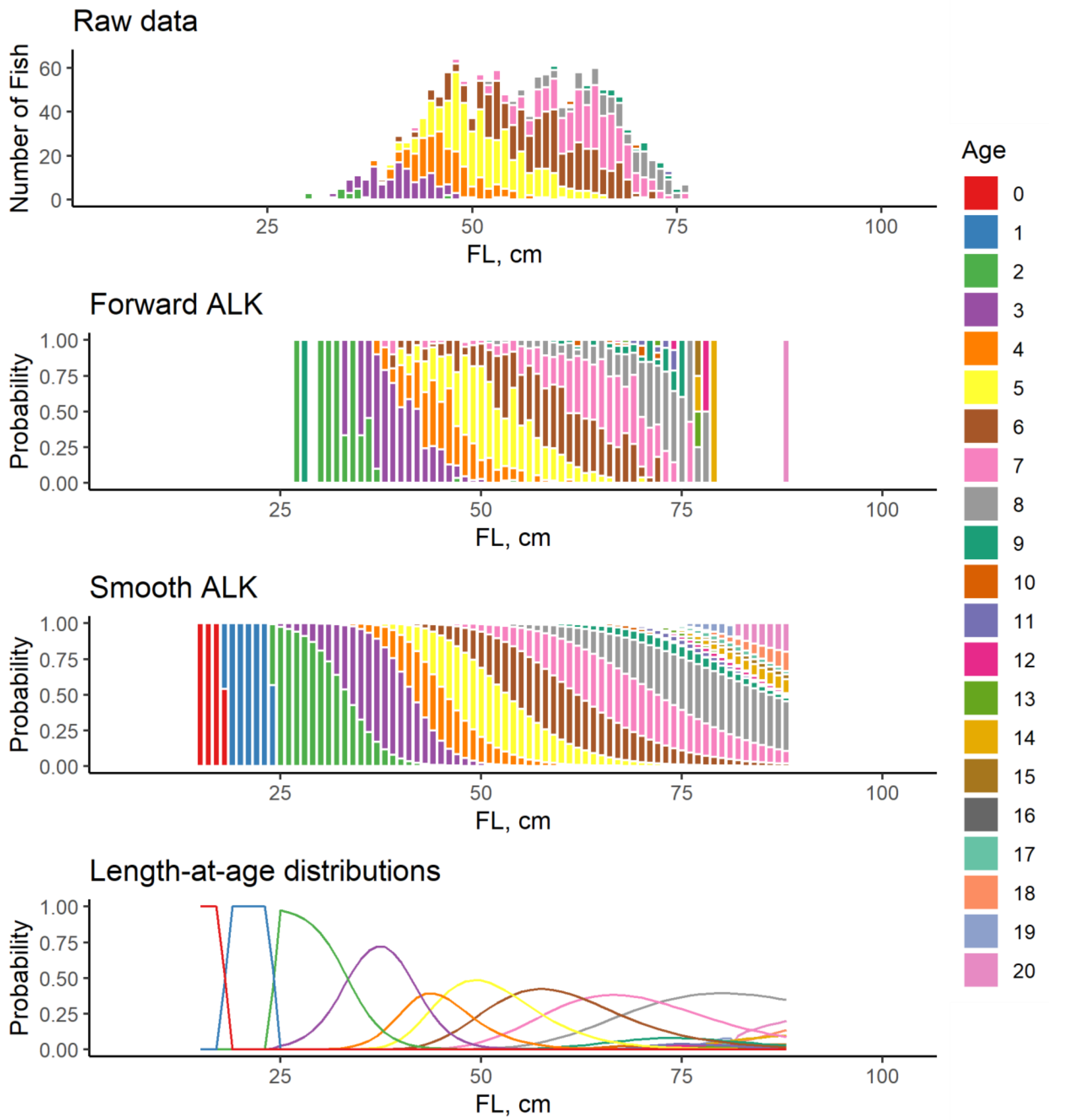

Figure 74. Age data and derived ALKs for 2013 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

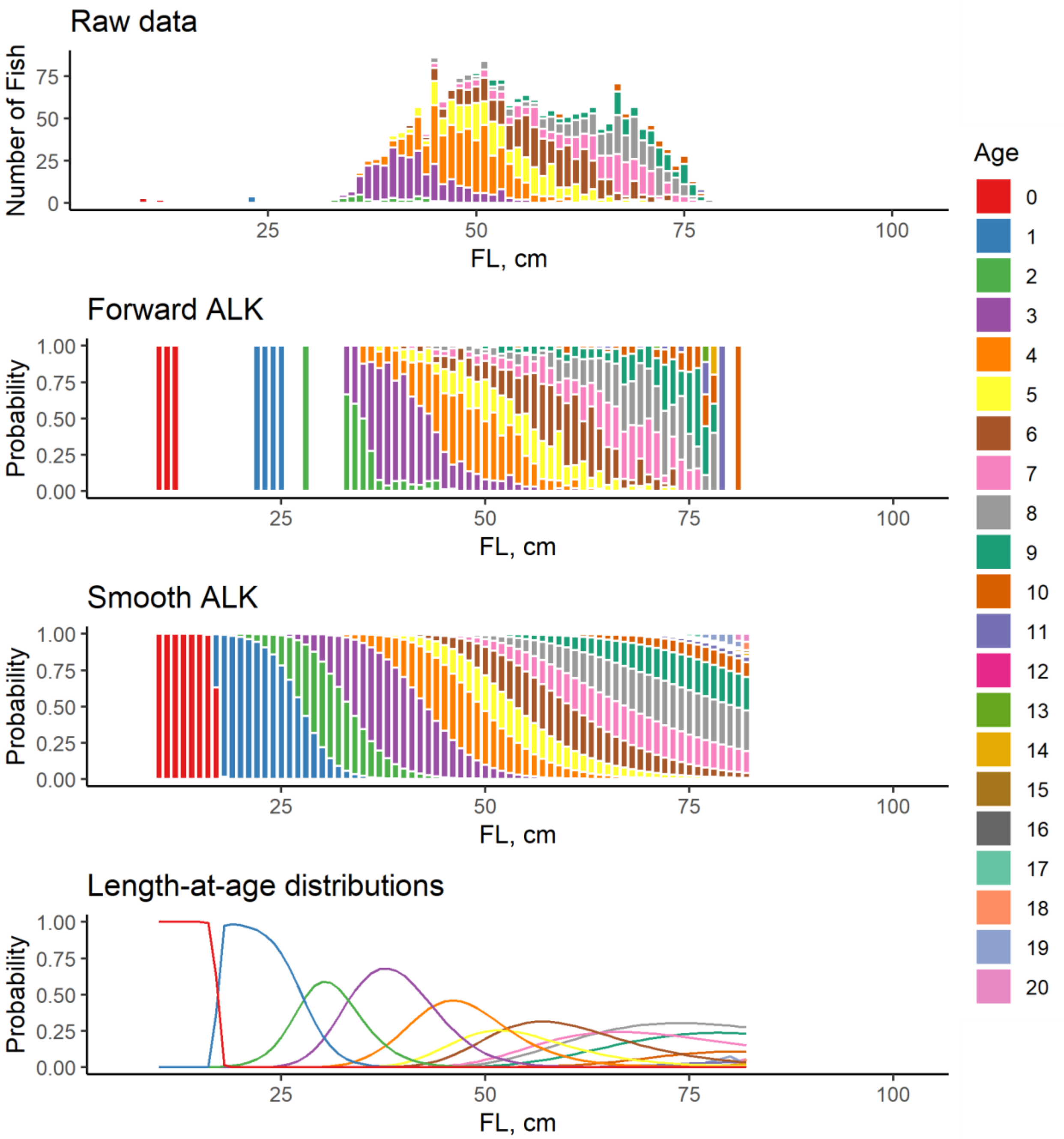

Figure 75. Age data and derived ALKs for 2014 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

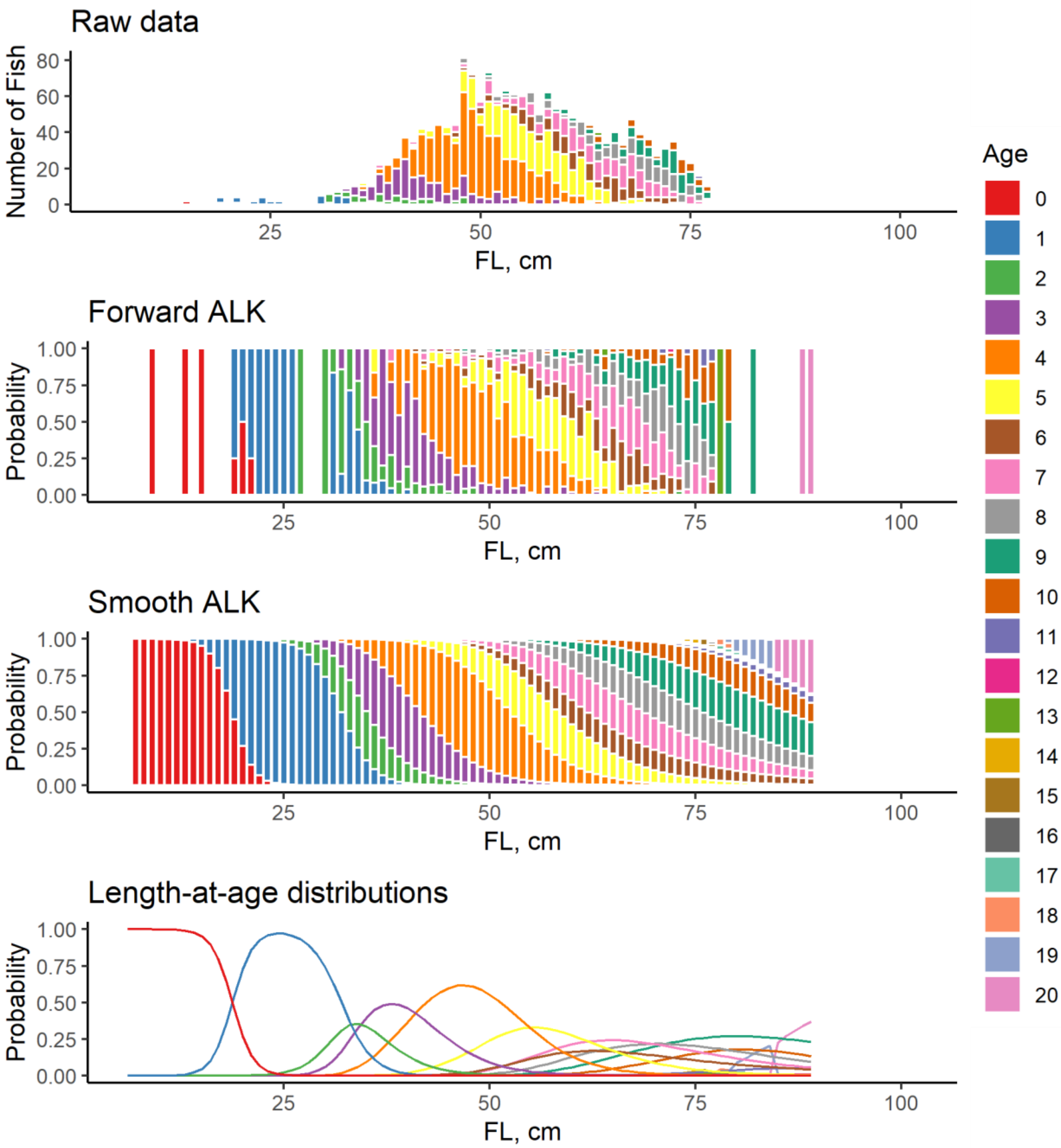

Figure 76. Age data and derived ALKs for 2015 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

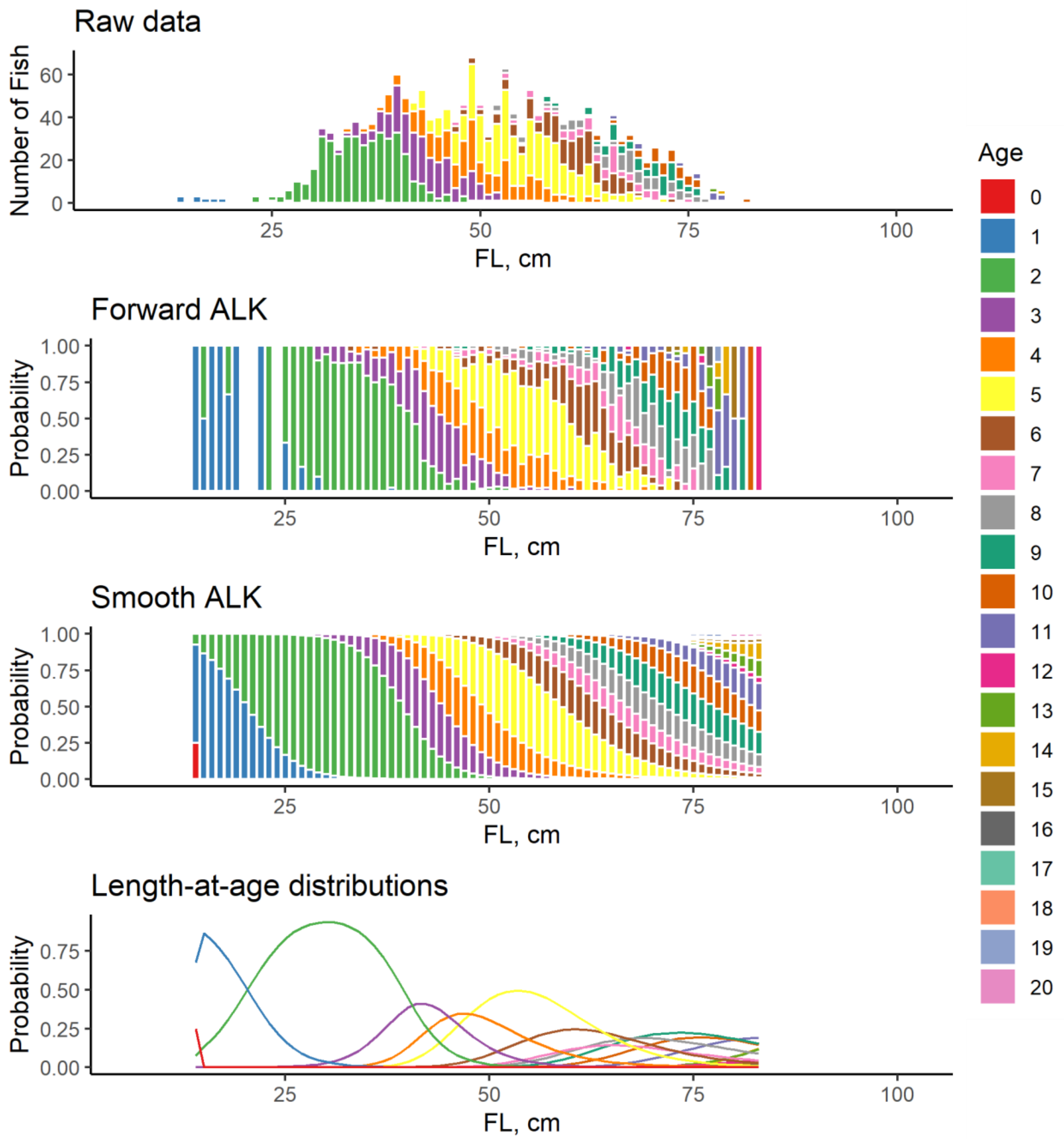

Figure 77. Age data and derived ALKs for 2016 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

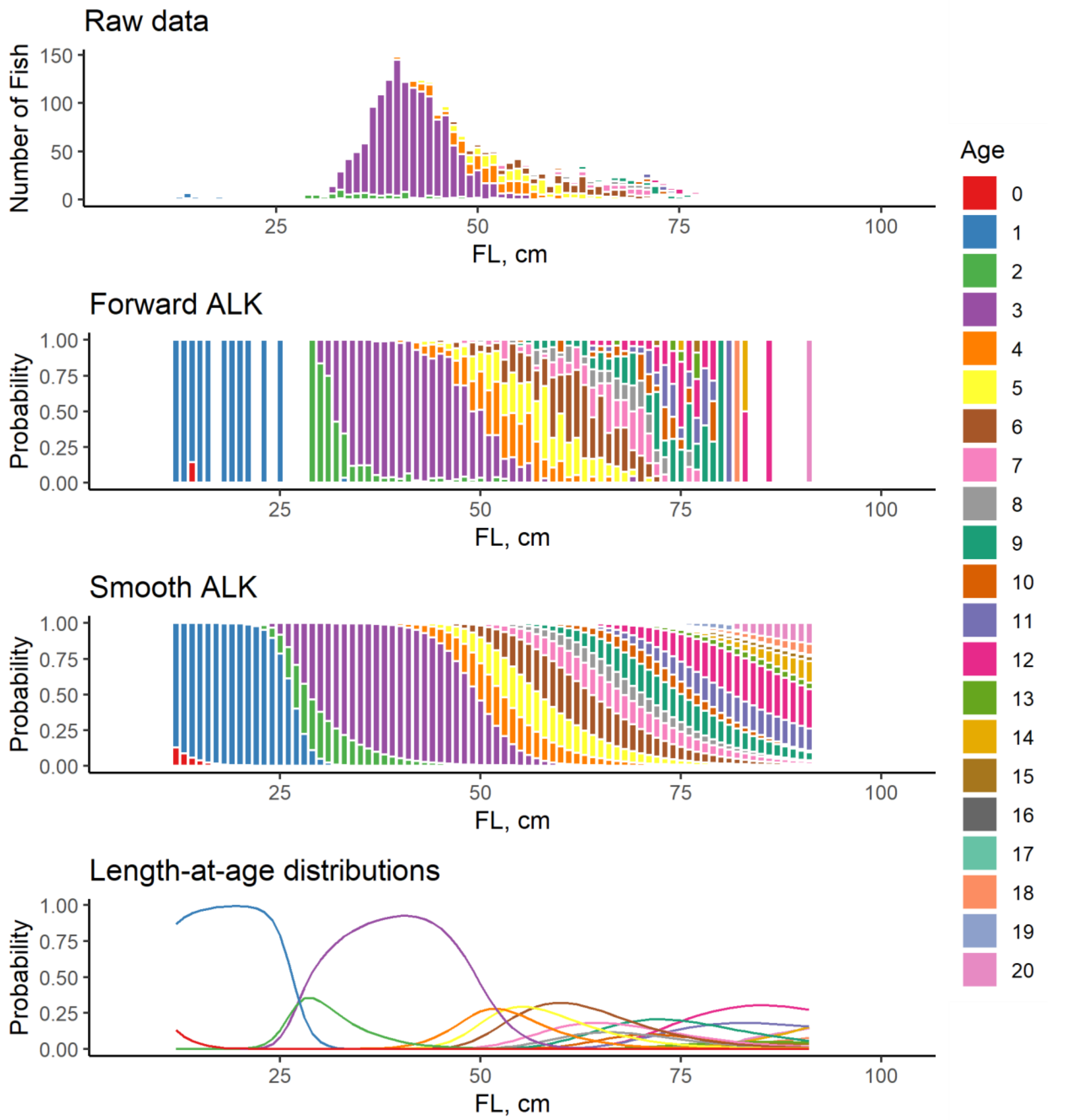

Figure 78. Age data and derived ALKs for 2017 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

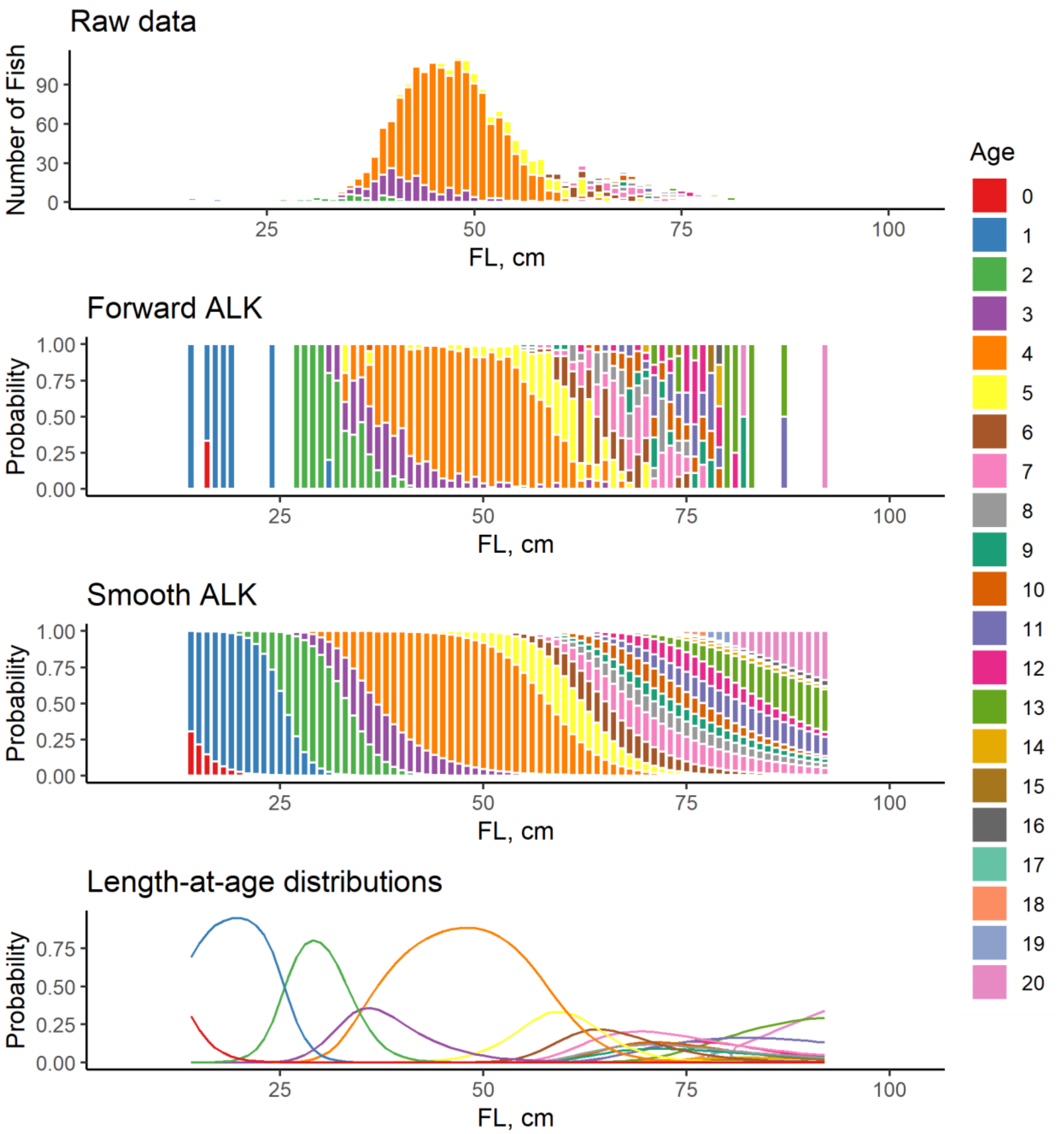

Figure 79. Age data and derived ALKs for 2018 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.

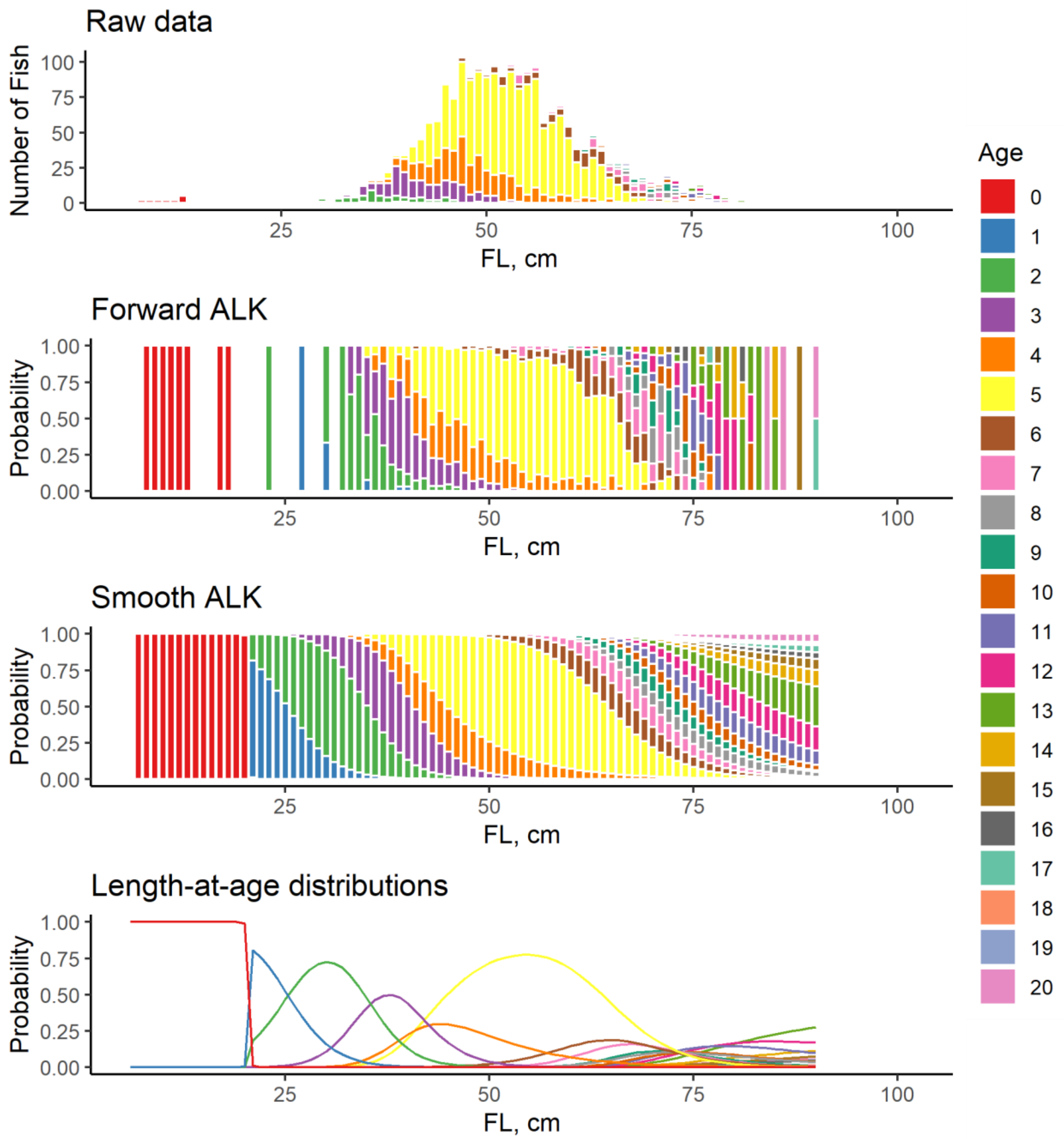

Figure 80. Age data and derived ALKs for 2019 in the E region. The top panel shows the raw data, the second panel shows the probability of age at length resulting from the classic ALK, the third panel shows probability of age at length resulting from the smooth ALK and the last panel shows the length distributions for each age group.