A review of king mackerel (*Scomberomorus cavalla)* age data collected from the Gulf of America from 1986 to 2024, with updated growth estimates

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A review of king mackerel (*Scomberomorus cavalla)* age data collected from the Gulf of America from 1986 to 2024, with updated growth estimates

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Introduction

This is the fifth SEDAR (Southeast Data Assessment and Review) for king mackerel, the most recent being the SEDAR38 update assessment (terminal year = 2017) conducted in 2020. The objectives of this report are to 1) summarize the age-at-length data by fishing year (FY), fishery, mode, and gear; 2) describe ageing protocols and provide estimates of ageing error; and 3) provide updated sex-specific growth parameter estimates given new data collected since 2017 and new parameterizations available for variance in growth functions since the previous stock assessment.

Methods

Sample Collection and Subsampling

Otoliths were collected from 1986 to 2024, with ages from 2018-2024 representing new samples collected since the previous stock assessment update (SEDAR38U, 2020). Samples were collected from the Gulf of America as well as the mixing zone as defined in SEDAR38U (2020). Data providers included the Panama City Laboratory (PCLab), Gulf Fisheries Information Network (GulfFIN), and Florida Fish and Wildlife Research Institute (FWRI). Samples were collected from commercial and recreational fleets as well as fishery-independent samples. Fishery-dependent samples were collected via the Trip Interview Program (TIP), Recreational Fisheries Information Network (RECFIN, FIN-BIOSTAT), Marine Fisheries Recreational Statistics Survey (MRFSS), Florida Fish and Wildlife Research Institute (FWRI-FDM), Beaufort Lab Headboat Survey (HB), Southeast Region Headboat Survey (SRHS), Cooperative Research Program (CO-OP), Louisiana Department of Wildlife and Fisheries (LADWF), Galveston Observer Program (GOP), and PCLab. Fishery independent samples were collected by the NMFS Pascagoula Lab, PCLab, Expanded Stock Assessment Survey (EASA), CO-OP, and FWRI fishery independent monitoring program (FWRI-FIM). Samples were collected from fishery-dependent catches taken with hand-lines, bottom longlines, seine nets, gillnets, trawls, and spears. Fishery-independent samples were collected with bottom longlines, hand-lines, gillnets, traps, and trawls.

Subsampling was conducted in 2012 due to a very large influx of commercial samples from Louisiana (Palmer et al., 2013). A total of n = 1,000 otoliths were selected with a simple random design from among all LA COM samples received in 2012. All other samples from that year were processed for ageing. From 2013 to 2024, all king mackerel otoliths were subsampled to prevent oversampling the large inventory of otoliths received annually and to facilitate dataprovision timelines. Subsamples were selected randomly from among several strata including year, season, gear, mode, sex and length bin. Seasons included 3-month intervals for winter (Dec, Jan, Feb), spring (Mar, Apr, May), summer (Jun, Jul, Aug), and fall (Sep, Oct, Nov), and lengths were partitioned into 50 mm bins. All fish <600 or >900 mm FL were included in the subsample, as well as all samples in a single stratum combination with <10 available samples. The remainder of the samples were randomly selected by the inverse weight of the target sample size (n = 10 per stratum) versus the total number of samples per stratum. Samples with an unknown gear type were excluded from the subsample pool.

Age Estimation and Error

Age was estimated for king mackerel using sagittal otoliths (Beaumariage, 1973) with a 2-stage approach. Otoliths from males <800 mm and females <900 mm fork length (FL) were aged whole using reflected light. Otoliths from fish with lengths exceeding each sex-specific threshold were sectioned with an Isomet slow-speed wafering saw (DeVries and Grimes, 1997), adhered to a glass microscope slide and examined with transmitted light (GSMFC, 2003; NMFS, 2008). Annuli were enumerated for whole otoliths following the methods described in Johnson et al. (1983) and for sectioned otoliths as described in Waltz (1986). Ages provided by PCLab were estimated by multiple readers over the time series: R1 (2003-2005; 2013-2024), R2 (1986-2002), R3 (2006-2011), and R4 (2012). Reader 1 became the only primary ager for PCLab starting in 2013 and remained through 2024. Reader proficiency was evaluated with a reference set developed in 2010 consisting of 100 whole and 100 sectioned otoliths with consensus ages. Percent agreement (PA), absolute average percent error (APE), and absolute CV (ACV) were the primary metrics for determining precision in age estimates with a target APE threshold of ≤5.0% (see Palmer et al., 2007). A description of ageing methods and proficiency evaluation for years prior to 2013 is available in Palmer et al. (2013).

Calendar ages were converted from annuli counts conditional on their edge type and calendar date-at-capture, which is necessary to assign fish to the correct year-class for input into the assessment model. Most individuals complete annulus formation in spring (Johnson et al., 1983). Therefore, fish captured from 1) January-May with a marginal increment >35% of the previous increment; 2) June to July 15th with 3 or more annuli and a marginal increment >35% larger than the previous increment; or 3) fish with 2 or fewer annuli and a marginal increment >70% of the previous increment (Palmer et al., 2013). Calendar age was equal to annuli count for all fish captured on or after July 16th. Fractional age was calculated as the difference between calendar age and capture date relative to July 1st, the expected date of peak spawning (Fitzhugh et al., 2008), added to the calendar age (Palmer et al., 2013).

Ageing error-at-age was estimated using reference set reads from two expert readers (PCLab-R1 and FWRI-R2). One set of reads was available for PCLab-R1 from 2013 whereas three sets of reads were available for FWRI-R2 from different years (2011, 2012, and 2014). Therefore, R2's modal age was used for each age estimate of the reference set to avoid giving disproportionate weight to one reader's reference set ages. The median age was used in place of the mode when only unique ages were estimated for a given reference set sample. As with multiple reads from a single reader, reference set reads from readers providing relatively small numbers of production ages were not included in ageing error models because their reads would disproportionately impact ageing error estimates relative to that source of error in the age data.

Candidate models for estimating bias and precision were fit to modal age tallies of reference set reads given several parameterization scenarios in the R package (R Core Team, 2025) "AgeingError" developed by the Northwest Fisheries Science Center (Punt et al., 2008; Thorson et al., 2008). Model scenarios for estimating precision included 1) constant CV; 2) curvilinear SD; 3) curvilinear CV; 4) SD as a linear function of age, or 5) CV as a linear function of age. Akaike's information criterion (AIC), a correction for small sample size (AICc), and the bayesion information criterion (BIC), as well as diagnostic plots, were used to select the best-fit model to describe ageing error. Although sectioned otoliths represent a relatively small portion of the production age data, reference set reads for whole and sectioned otoliths were modeled without imposing any weighting scheme. Ageing error was estimated for both readers as a single set of age-specific estimates (i.e., mirrored) for input into the stock assessment model.

Growth

King mackerel growth was modeled with the von Bertalanffy growth equation in AD Model Builder (Fournier et al., 2012) with separate growth equations for each sex. The probability distributions for all VBG models were specified to follow a truncated normal distribution to correct for size-at-age observations missing from the dataset due to minimum length limits (McGarvey and Fowler, 2002; Diaz et al., 2004). Model variance was estimated with multiple parameterizations including: 1) constant SD, 2) constant CV, 3) CV as a linear function of age, or 4) CV as a linear function of length-at age. For model types 3 and 4, an initial variance parameter was estimated as a linear function from an initial age (A_{min}; age-0.1) to A_{max} (ages-1 to 3 yrs). A second variance parameter was then estimated as a linear function from A_{max} to the maximum observed age of 24 yrs. Variance models for constant SD or CV included only a single variance parameter. The age-at-length data were not weighted.

Results and Discussion

Samples Collected

A total of 5,474 samples were aged from 2018 to 2024. Samples from 2024 represent a complete calendar year but an incomplete fishing year because no samples collected between Jan 1st and June 30th, 2025 were processed for ageing. Samples from the mixing zone comprised 8% and 4% of the total aged in FY's 2018 and 2019, respectively but <1% of aged samples since FY 2019 (Table 1). Age samples from the new data period were provided by the PCLab and GulfFIN with PCLab providing more than 93% of all samples in the most recent years (Table 2). The majority of the ages provided by GulfFIN were collected in FL and estimated by FWRI-R2 (~75%). Age samples from the recreational fishery have declined dramatically to less than 10% of the total each year since the start of FY 2021 (Table 3). In contrast, age samples from the recreational fleet comprised between 24 and 86% of the total samples among all years prior to FY 2021 with the primary source of age samples intermittently alternating between COM and REC fleets throughout the time series. Nearly all age samples collected from fishery-dependent sources were taken with handline gears (Tables 4a and 4b). No fishery-independent age samples have been collected since the start of FY 2018 (Table 4c). Prior to 2018, large portions of annual age samples were collected from NWF, TX, and LA. However, the majority of new samples have been collected from fish landed in Louisiana or Alabama and very few from NWF or TX (Table 5, Figure 1). Since the start of FY 2018, the number of age samples collected from other mackerel states has been infrequent and highly variable (0 to 30%). Although confounded with subsampling, the number of samples aged has declined sharply since 2011.

Ageing Error

Reference set reads were available for expert reader 1 (R1) from 2012 and for R2 from 2011, 2012, and 2014. Reference set reads for other PCLab readers prior to 2013 were not available but are summarized in Palmer et al. (2013). Reference set reads from readers outside of PCLab and FWRI were available, but these sources provided 7.2% of the age data since 2012 so they were not included in age error estimation. The percent agreement (PA), absolute average percent error (APE), and absolute average CV for PCLab-R1 were 91.0%, 1.5%, and 2.1, respectively. Mean (±SD) estimates of PA, APE, and ACV for modal ages from FWRI-R2 were 77.7% (±2.02), 3.5% (±0.5), and 5.0 (±0.7), respectively. Reference set reads from previous data periods (i.e., prior to 2018) are still applicable for estimating reference set error because the same expert readers provided the overwhelming majority of age estimates since 2013. Reference set reads from earlier in the data period may be less likely to have issues with potential memorization of samples in the reference collection. More recent reference set reads were not available from PCLab-R1 due to their unexpected and sudden retirement. Additional reference set reads were not necessary for FWRI-R2 since reads from multiple years were available and consistently had very high accuracy and precision.

The best-fit model for ageing error-at-age fit curvilinear CV for both the reference set and expert readers' modal age tallies (Figure 2). Curvilinear CV was fit due to a slight increase in error for age estimation from 3-6 yrs. However, values for CV-at-age were very low across all ages (Table 6). Visual inspection of reference set reads with Bland-Altman plots (Figure 3) indicated models with estimated bias were not necessary due to high accuracy across all age classes in the reference set.

Growth

Growth models (Table 7) fit to sex-specific age-at-length data estimated increased values of L_∞ for both sexes and much lower k values (Table 8) compared to those reported in previous empirical estimates (Lombardi, 2014) or estimated internal to a stock assessment growth model (SEDAR38, 2014). For the L_∞ parameter, the best-fit VBG equation estimated $L_\infty = 1339.6$ (±9.0 mm) for females and 1039.5 (±6.7 mm) for males. Compared to SEDAR38 and SEDAR38U, this represents a 25.0% and 12.3% increase in expected mean length at asymptotic max size for females and males, respectively. These parameters represent a smaller increase for females (7.0%) and larger increase for males (18.7%) compared to empirical estimates provided for SEDAR38 (Lombardi, 2013). Estimates provided here are even more substantially different for the k parameter with k estimated to be more than 3-fold lower than empirical estimates for males (0.1580 ±0.005) and 26.1% lower for females (0.1395 ±0.003). Differences were less dramatic compared to internal estimates from SEDAR38 for males (2.2-fold lower) but of greater difference than for females (2.8-fold higher). One explanation for such large model parameter discrepancies is the different methods for estimating variance in the VBG models fit to the data as well as the generally poor estimates of t_0, which had relatively large negative values in all but one model estimate (Lombardi, 2013). For SEDAR38, empirical models were fit to observed length-at-age data using a constant value for the σ or CV parameters without the option to parameterize variance as a function of age or length-at-age. For both sexes, a model with variance parameterized to change as a function of age were significantly better fit (>2ΔAICc units lower) than models with constant variance parameters. In both cases, a model with variance parameterized as a function of length-at-age was the best fit to the observed data compared to a model with variance parameterized only as a function of age. However, the difference was only modestly improved for males (ΔAICc = 9.0) and not-significantly different for females (ΔAICc = 1.0). For females, the best-fit model indicated that variance was larger-at-age through age-2 before decreasing across all remaining age classes. For males, variance was larger through age-3 before decreasing to a lesser value across all remaining age-classes. Although t_0 was estimated, growth models fit a linear interpolation from age-0.01 to age-0.1 whereafter growth followed the parameters estimated in the VBG equation (Figure 4).

Another possible explanation to explain large differences in growth parameters could be due to changes in the sources of samples collected (e.g., fishery, mode, gear). Additional examination of frequency histograms indicated a greater proportion of older individuals in the new age data (Figure 5). Examinations of age data specific to mackerel state (Figure 6) indicated that age-frequency distributions for Louisiana, the primary contributor to age data for the new period, were very similar to historical age-frequency distributions. However, age frequency distributions for most other mackerel states did show increased proportions of older fish. In contrast, age samples collected from west Florida showed disproportionately large increases of younger age classes. Age-frequency data from shore and private modes indicated a similarly high proportion of young fish in the new data period whereas commercial modes and headboats showed increased proportions of older individuals (Figure 7). Age-frequencies data from charterboats was very similar between data periods.

A third explanation for these differences could be the relative position of data from the new period in the length-at-age data if predominantly larger, older fish were added to the dataset used to fit the new growth curves. A scatterplot of sex-specific length-at-age color-coded by data period indicated that the new data period fell overwhelmingly around the middle of the data cloud, indicating that samples falling nearer the extremes of length at a given age came predominantly from older collections. Thus, new data would be expected to reduce uncertainty around growth parameter estimates, instead of shifting them, if previous models accurately described sex-specific growth. Therefore, the observed shifts in growth parameters are likely due to new modeling scenarios (more complex fits of variance) rather than dramatic changes to the data modeled for growth. However, the highlighted shifts in age-frequencies by period, mackerel state, and mode during the new data period will likely still help inform modeling strategies during the assessment process.

Literature Cited

Beaumariage, D.S. 1973. Age, growth and reproduction of king mackerel *Scomberomorus cavalla*, in Florida. Florida Department of Natural Resources. Florida Marine Research Publications. 1:1-45.

DeVries, D.A. and C.B. Grimes. 1997. Spatial and temporal variation in age and growth of king mackerel, *Scomberomorus cavalla*, 1977 – 1992. Fishery Bulletin. 95:694-708.

Diaz, G.A., C.E. Porch, and M. Ortiz. 2004. Growth models for red snapper in U.S. Gulf of Mexico waters estimated from landings with minimum size limit restrictions. SEDAR7-AW-01. 13 pp.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software. 27:233-249

Fitzhugh, G.R., C.F. Levins, W.T. Walling, M. Gamby, H. Lyon, and D.A. DeVries. 2008. Batch fecundity and an attempt to estimate spawning frequency of king mackerel (*Scomberomorus cavalla*) in U.S. waters. SEDAR16-DW. NMFS Panama City Laboratory Contribution 08-01.

GSMFC (Gulf States Marine Fisheries Commission). 2003. A practical handbook for determining ages of Gulf of Mexico fishes. Publication 111. Ocean Springs, MS. 13 pp.

Johnson, A.G., W.A. Fable Jr., M.L. Williams, and L.E. Barger. 1983. Age, growth and mortality of king mackerel, *Scomberomorus cavalla*, from the southeastern United States. Fishery Bulletin. 81:97-106.

Lombardi, L. 2014. Growth models for king mackerel from the south Atlantic and Gulf of Mexico. SEDAR38-AW-01. SEDAR, North Charleston, SC. 62. pp.

McGarvey, R. and A.J. Fowler. 2002. Seasonal growth of King George whiting (*Sillaginodes punctata*) estimated from length-at-age samples of the legal-size harvest. Fishery Bulletin. 100(3): 545-559

NMFS. 2008. Procedure manual for the age, growth, and reproduction lab. Fisheries biology group. National Marine Fisheries Service. Panama City Laboratory. 249 pp.

Palmer, C.L., R.A. Farsky, C. Gardner, and L.A. Lombardi-Carlson. 2007. The use of an otolith reference collection to monitor reader precision for red grouper, *Epinephelus morio*. Panama City Laboratory Contribution 06-11.

Palmer, C., D. Devries, C. Fioramonti, and H. Lang. 2013. A review of Gulf of Mexico and Atlantic king mackerel (*Scomberomorus cavalla*) age data, 1986 – 2013, from the Panama City Laboratory, Southeast Fishery Science Center, NOAA Fisheries Service. SEDAR38-DW-15. SEDAR, North Charleston, SC. 59 pp.

Punt, A.E., D.C. Smith, K. KrusicGolub, and S. Robertson. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia's southern and eastern scalefish and shark fishery. Canadian Journal of Fisheries and Aquatic Sciences. 65:1991-2005.

R Core Team. 2025. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org

SEDAR (Southeast Data, Assessment, and Review) 38 Stock Assessment Report. 2014. Gulf of Mexico King Mackerel. SEDAR, North Charleston, SC. 465 pp.

SEDAR (Southeast Data, Assessment, and Review) 38 Assessment Update Report. 2020. Gulf of Mexico King Mackerel Assessment Update Report. SEDAR, North Charleston, SC. 82 pp.

Thorson, J.T., I. Stewart, and A.E. Punt. 2008. Data input and stepwise model selection in R for the Punt et al. (2008) ageing error model. Technical Document for the Northwest Fisheries Science Center. 7 pp.

Waltz, W. 1986. Data report on preliminary attempts to monitor age, size, and reproductive states of king mackerel in the south Atlantic Bight. South Carolina Wildlife and Marine Resources Department. MARMAP reproduction for contract 6-35147.

TABLES

Table 1. Number of king mackerel age samples by Stock (Gulf of America, GOA; winter mixing zone, MZ; or unknown, UN) by fishing year (FY) from 1986 to 2024 in the Gulf of America.

FY	GOA	MZ	UN	Total
1985-1986	15	0	0	15
1986-1987	612	0	17	629
1987-1988	841	1	2	844
1988-1989	864	20	5	889
1989-1990	1,106	57	3	1,166
1990-1991	887	97	5	989
1991-1992	1,521	112	26	1,659
1992-1993	1,122	42	4	1,168
1993-1994	1,435	20	6	1,461
1994-1995	958	13	15	986
1995-1996	927	79	0	1,006
1996-1997	852	13	8	873
1997-1998	497	91	0	588
1998-1999	321	81	3	405
1999-2000	301	48	0	349
2000-2001	209	118	1	328
2001-2002	922	217	6	1,145
2002-2003	1,622	160	2	1,784
2003-2004	1,370	71	16	1,457
2004-2005	1,158	117	0	1,275
2005-2006	1,097	73	7	1,177
2006-2007	1,011	79	0	1,090
2007-2008	1,803	78	0	1,881
2008-2009	1,751	34	24	1,809
2009-2010	2,216	56	2	2,274
2010-2011	2,071	124	0	2,195
2011-2012	2,669	28	1	2,698
2012-2013	2,341	4	1	2,346
2013-2014	1,651	66	2	1,719
2014-2015	1,445	49	7	1,501
2015-2016	1,670	3	3	1,676
2016-2017	1,446	46	2	1,494
2017-2018	972	81	0	1,053
2018-2019	1,002	88	2	1,092
2019-2020	1,133	47	0	1,180
2020-2021	441	0	0	441
2021-2022	701	3	0	704
2022-2023	732	1	0	733
2023-2024	650	5	30	685
2024-2025	265	2	1	268
Total	**44,611**	**2,224**	**201**	**47,036**

Table 2. Number of king mackerel age samples by data provider (Florida Fish and Wildlife Research Institute, FWRI; Gulf Fisheries Information Network, GulfFIN; and Panama City Lab database, AGR; BSD) by fishing year (FY) from 1986 to 2024 in the Gulf of America.

FY	FWRI	GulfFIN	PCLab	PCLab-AGR	PCLab-BSD	Total
1985-1986	0	0	15	0	0	15
1986-1987	0	0	629	0	0	629
1987-1988	0	0	844	0	0	844
1988-1989	0	0	889	0	0	889
1989-1990	0	0	1,166	0	0	1,166
1990-1991	0	0	989	0	0	989
1991-1992	0	0	1,659	0	0	1,659
1992-1993	0	0	1,168	0	0	1,168
1993-1994	0	0	1,461	0	0	1,461
1994-1995	0	0	986	0	0	986
1995-1996	0	0	1,006	0	0	1,006
1996-1997	0	0	873	0	0	873
1997-1998	0	0	588	0	0	588
1998-1999	0	0	405	0	0	405
1999-2000	0	0	349	0	0	349
2000-2001	0	0	328	0	0	328
2001-2002	0	74	1,071	0	0	1,145
2002-2003	0	398	1,386	0	0	1,784
2003-2004	0	426	1,031	0	0	1,457
2004-2005	15	536	724	0	0	1,275
2005-2006	0	440	737	0	0	1,177
2006-2007	1	413	676	0	0	1,090
2007-2008	3	496	1,382	0	0	1,881
2008-2009	19	368	1,422	0	0	1,809
2009-2010	11	425	1,838	0	0	2,274
2010-2011	10	370	1,815	0	0	2,195
2011-2012	1	742	1,955	0	0	2,698
2012-2013	0	345	1,765	213	23	2,346
2013-2014	1	340	44	394	940	1,719
2014-2015	3	137	0	495	866	1,501
2015-2016	1	770	0	209	696	1,676
2016-2017	5	602	0	274	613	1,494
2017-2018	2	248	0	250	553	1,053
2018-2019	0	266	0	228	598	1,092
2019-2020	0	208	0	0	972	1,180
2020-2021	0	295	0	0	146	441
2021-2022	0	50	0	0	654	704
2022-2023	0	54	0	0	679	733
2023-2024	0	11	0	0	674	685
2024-2025	0	16	0	0	252	268
Total	**72**	**8,030**	**29,205**	**2,063**	**7,666**	**47,036**

Table 3. Number of king mackerel age samples collected from each fishery (commercial, COM; fishery-independent, FI; recreational, REC; or unknown, UN) by fishing year (FY) from 1986 to 2024 in the Gulf of America.

FY	COM	FI	REC	UN	Total
1985-1986	0	0	0	15	15
1986-1987	27	0	340	262	629
1987-1988	10	20	245	569	844
1988-1989	20	4	508	357	889
1989-1990	92	25	889	160	1,166
1990-1991	133	2	838	16	989
1991-1992	503	0	1,156	0	1,659
1992-1993	161	0	1,004	3	1,168
1993-1994	773	0	688	0	1,461
1994-1995	225	0	761	0	986
1995-1996	357	0	586	63	1,006
1996-1997	77	0	748	48	873
1997-1998	189	0	396	3	588
1998-1999	94	0	310	1	405
1999-2000	95	0	254	0	349
2000-2001	165	8	155	0	328
2001-2002	741	3	401	0	1,145
2002-2003	718	2	1,064	0	1,784
2003-2004	581	1	875	0	1,457
2004-2005	567	21	687	0	1,275
2005-2006	488	6	683	0	1,177
2006-2007	384	6	700	0	1,090
2007-2008	1,324	3	554	0	1,881
2008-2009	1,161	19	629	0	1,809
2009-2010	1,371	28	875	0	2,274
2010-2011	1,385	67	743	0	2,195
2011-2012	1,651	6	1,041	0	2,698
2012-2013	1,619	15	712	0	2,346
2013-2014	1,028	19	672	0	1,719
2014-2015	866	3	632	0	1,501
2015-2016	696	1	979	0	1,676
2016-2017	587	5	900	2	1,494
2017-2018	512	2	539	0	1,053
2018-2019	497	0	595	0	1,092
2019-2020	893	0	287	0	1,180
2020-2021	146	0	295	0	441
2021-2022	636	0	68	0	704
2022-2023	677	0	56	0	733
2023-2024	668	0	17	0	685
2024-2025	250	0	18	0	268
Total	**22,367**	**266**	**22,900**	**1,503**	**47,036**

Table 4a. Number of king mackerel age samples collected from the commercial fleet by fishing year (FY) and gear type (gillnet, GN; handline, HL; bottom longline, LL; seine net, SN; spear, SP; trawl, TW; or unknown gear type, UN) from 1986 to 2024 in the Gulf of America.

FY	GN	HL	LL	SN	SP	TW	UN	Total
1985-1986								0
1986-1987		25		2				27
1987-1988		10						10
1988-1989	1	19						20
1989-1990		4					88	92
1990-1991	8	121					4	133
1991-1992	83	420						503
1992-1993		161						161
1993-1994	108	665						773
1994-1995	11	214						225
1995-1996	16	341						357
1996-1997		77						77
1997-1998	9	180						189
1998-1999	27	67						94
1999-2000		95						95
2000-2001	18	147						165
2001-2002	245	496						741
2002-2003	265	396				57		718
2003-2004	61	479				41		581
2004-2005	43	448				70	6	567
2005-2006	24	450					14	488
2006-2007	41	343						384
2007-2008	253	969					102	1,324
2008-2009	135	927	3				96	1,161
2009-2010	242	1,031					98	1,371
2010-2011	222	1,065					98	1,385
2011-2012	262	1,318					71	1,651
2012-2013	476	1,105					38	1,619
2013-2014	266	762						1,028
2014-2015	209	657						866
2015-2016	180	516						696
2016-2017	189	398						587
2017-2018	164	348						512
2018-2019	53	444						497
2019-2020	55	838						893
2020-2021		146						146
2021-2022		636						636
2022-2023	69	608						677
2023-2024	87	581						668
2024-2025		250						250
Total	**3,822**	**17,757**	**3**	**2**	**0**	**168**	**615**	**22,367**

Table 4b. Number of king mackerel age samples collected from the recreational fleet by fishing year (FY) and gear type (gillnet, GN; handline, HL; bottom longline, LL; seine net, SN; spear, SP; trawl, TW; or unknown gear type, UN) from 1986 to 2024 in the Gulf of America.

FY	GN	HL	LL	SN	SP	TW	UN	Total
1985-1986								0
1986-1987		340						340
1987-1988		245						245
1988-1989		508						508
1989-1990		889						889
1990-1991		774					64	838
1991-1992	3	1,138					15	1,156
1992-1993		1,004						1,004
1993-1994		688						688
1994-1995		761						761
1995-1996		577			9			586
1996-1997		748						748
1997-1998		396						396
1998-1999		310						310
1999-2000		254						254
2000-2001		155						155
2001-2002		401						401
2002-2003		1,064						1,064
2003-2004		875						875
2004-2005		674			13			687
2005-2006		683						683
2006-2007		700						700
2007-2008		551			3			554
2008-2009		629						629
2009-2010		875						875
2010-2011		743						743
2011-2012		1,039			2			1,041
2012-2013		712						712
2013-2014		672						672
2014-2015		632						632
2015-2016		979						979
2016-2017		899			1			900
2017-2018		539						539
2018-2019		595						595
2019-2020		287						287
2020-2021		295						295
2021-2022		68						68
2022-2023		56						56
2023-2024		17						17
2024-2025		18						18
Total	**3**	**22,790**	**0**	**0**	**28**	**0**	**79**	**22,900**

Table 4c. Number of king mackerel age samples collected with fishery independent gears by fishing year (FY) and gear type (gillnet, GN; handline, HL; bottom longline, LL; seine net, SN; spear, SP; trawl, TW; or unknown gear type, UN) from 1986 to 2024 in the Gulf of America.

FY	GN	HL	LL	SN	SP	TW	UN	Total
1985-1986								0
1986-1987								0
1987-1988		2	18					20
1988-1989			4					4
1989-1990			25					25
1990-1991		1				1		2
1991-1992								0
1992-1993								0
1993-1994								0
1994-1995								0
1995-1996								0
1996-1997								0
1997-1998								0
1998-1999								0
1999-2000								0
2000-2001		8						8
2001-2002		3						3
2002-2003		1	1					2
2003-2004	1							1
2004-2005		4	2			15		21
2005-2006		6						6
2006-2007		6						6
2007-2008		1				2		3
2008-2009		1				18		19
2009-2010		5				23		28
2010-2011		7				60		67
2011-2012						6		6
2012-2013						15		15
2013-2014		1				18		19
2014-2015		3						3
2015-2016						1		1
2016-2017		4				1		5
2017-2018		1				1		2
2018-2019								0
2019-2020								0
2020-2021								0
2021-2022								0
2022-2023								0
2023-2024								0
2024-2025								0
Total	**1**	**54**	**50**	**0**	**0**	**161**	**0**	**266**

Table 5. Number of king mackerel age samples by mackerel state (Mexico, MEX; Texas, TX; Louisiana, LA; Mississippi, MS: Alabama, AL; northwest Florida, NWF; west Florida, WF; southwest Florida, SWF; south Florida, SF; not landed, NL; or unknown, UN) from 1986 to 2024 in the Gulf of America.

FY	MEX	TX	LA	MS	AL	NWF	WF	SWF	SF	NL	UN	Total
1985-1986	0	15	0	0	0	0	0	0	0	0	0	15
1986-1987	0	167	50	69	132	192	2	0	17	0	0	629
1987-1988	102	382	75	60	172	50	0	0	3	0	0	844
1988-1989	163	336	68	80	83	133	0	0	26	0	0	889
1989-1990	241	344	58	16	7	440	0	0	60	0	0	1,166
1990-1991	103	181	41	97	18	447	0	0	102	0	0	989
1991-1992	178	443	305	58	4	410	123	0	138	0	0	1,659
1992-1993	0	214	292	47	9	345	215	0	46	0	0	1,168
1993-1994	198	147	566	0	8	244	243	29	26	0	0	1,461
1994-1995	0	56	347	0	0	300	196	48	39	0	0	986
1995-1996	0	0	158	0	0	560	148	61	79	0	0	1,006
1996-1997	0	0	0	0	0	751	101	0	21	0	0	873
1997-1998	0	0	0	0	0	406	82	0	100	0	0	588
1998-1999	0	0	0	20	1	156	74	52	102	0	0	405
1999-2000	0	0	0	66	4	145	41	45	48	0	0	349
2000-2001	0	0	0	18	0	127	5	59	119	0	0	328
2001-2002	0	24	217	12	68	318	14	24	468	0	0	1,145
2002-2003	0	55	257	31	234	500	203	77	427	0	0	1,784
2003-2004	0	61	273	50	74	568	282	1	148	0	0	1,457
2004-2005	0	252	260	47	62	224	235	20	160	15	0	1,275
2005-2006	0	257	333	14	65	294	110	0	104	0	0	1,177
2006-2007	0	168	358	25	122	226	70	0	120	1	0	1,090
2007-2008	0	291	1,051	3	43	118	49	141	182	3	0	1,881
2008-2009	0	210	959	0	69	290	37	52	173	19	0	1,809
2009-2010	0	238	1,052	0	91	437	207	30	208	11	0	2,274
2010-2011	0	265	1,036	0	58	277	280	12	257	10	0	2,195
2011-2012	0	362	1,185	4	172	353	224	59	338	1	0	2,698
2012-2013	0	404	1,007	7	77	194	174	89	394	0	0	2,346
2013-2014	0	309	576	1	140	235	117	48	289	1	3	1,719
2014-2015	0	29	619	4	60	493	90	27	165	3	11	1,501
2015-2016	0	57	424	42	77	833	93	2	147	1	0	1,676
2016-2017	0	86	272	59	167	654	75	62	112	5	2	1,494
2017-2018	0	45	294	31	8	380	26	75	188	2	4	1,053
2018-2019	0	96	338	14	83	290	74	22	167	0	8	1,092
2019-2020	0	68	672	9	191	48	72	0	106	0	14	1,180
2020-2021	0	1	85	0	162	55	134	3	1	0	0	441
2021-2022	0	19	252	1	396	11	22	0	3	0	0	704
2022-2023	0	6	401	1	189	15	50	0	71	0	0	733
2023-2024	0	1	402	0	165	7	15	3	87	0	5	685
2024-2025	0	2	250	0	0	14	0	0	2	0	0	268
Total	**985**	**5,591**	**14,533**	**886**	**3,211**	**11,540**	**3,887**	**1,041**	**5,243**	**72**	**47**	**47,036**

Table 6. Age-specific estimates of error-at-age from the best-fit model fit to modal-age tallies of reference set reads from two expert readers.

Ref_Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
CV	0.190	0.190	0.146	0.112	0.087	0.068	0.054	0.043	0.035	0.029	0.025
SD	0.190	0.190	0.292	0.337	0.349	0.341	0.324	0.304	0.283	0.264	0.248
Ref_Age	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
CV	0.021	0.019	0.017	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012
SD	0.235	0.225	0.219	0.216	0.215	0.216	0.219	0.223	0.229	0.236	0.244

Table 7. Output tables for combined and sex-specific von Bertalanffy growth models estimated for king mackerel length-at-age data for each variance parameterization scenario (Var Model). ΔAIC values indicate the change in AIC compared to the best-fit model (ΔAIC = 0) in each model group (green-shaded rows). Although t0 was estimated for each model, the model followed a linear interpolation from 0 to A_{lin}. The value for σ^1 indicates the estimated variance from A_{lin} to A_{min}, and σ^2 is the estimated variance from A_{min} to the maximum observed age in the data. Models with variance parameterized as having constant CV failed to converge.

Group	A_{lin}	A_{min}	Var Model	Obj Fxn	AIC	ΔAIC	L_∞	k	t_0	σ_1	σ_2
Sexes Combined	0.01	0.1	Constant sigma	250912.0	501831.0	4011.0	1150.4	0.1885	-2.66	103.54	--
	0.01	0.1	Constant CV	DNC	--	--	--	--	--	--	--
	0.01	0.1	Linear fxn age-1	248905.0	497820.0	0.0	1187.4	0.1580	-3.53	0.638	0.113
	0.01	0.1	Linear fxn age-2	249342.0	498695.0	875.0	1165.3	0.1735	-3.14	0.207	0.113
	0.01	0.1	Linear fxn age-3	249596.0	499202.0	1382.0	1155.6	0.1828	-2.87	0.163	0.113
	0.01	0.1	Linear fxn size-at-age-1	248906.0	497821.0	1.0	1187.4	0.1580	-3.53	0.654	0.113
	0.01	0.1	Linear fxn size-at-age-2	249318.0	498646.0	826.0	1164.3	0.1740	-3.13	0.215	0.113
	0.01	0.1	Linear fxn size-at-age-3	249556.0	499122.0	1302.0	1153.7	0.1840	-2.86	0.171	0.113
Females	0.01	0.1	Constant sigma	113778.0	227564.0	1146.0	1351.0	0.1381	-3.34	89.10	--
	0.01	0.1	Constant CV	DNC	--	--	--	--	--	--	--
	0.01	0.1	Linear fxn age-1	113218.0	226447.0	29.0	1345.3	0.1370	-3.51	0.352	0.098
	0.01	0.1	Linear fxn age-2	113205.0	226419.0	1.0	1339.5	0.1396	-3.44	0.139	0.097
	0.01	0.1	Linear fxn age-3	113230.0	226471.0	53.0	1337.6	0.1408	-3.38	0.116	0.097
	0.01	0.1	Linear fxn size-at-age-1	113219.0	226448.0	30.0	1345.4	0.1370	-3.51	0.361	0.098
	0.01	0.1	Linear fxn size-at-age-2	113204.0	226418.0	0.0	1339.6	0.1395	-3.44	0.142	0.097
	0.01	0.1	Linear fxn size-at-age-3	113228.0	226467.0	49.0	1337.3	0.1408	-3.38	0.118	0.097
Males	0.01	0.1	Constant sigma	60458.4	120925.0	215.0	1041.6	0.1588	-4.56	63.60	--
	0.01	0.1	Constant CV	DNC	--	--	--	--	--	--	--
	0.01	0.1	Linear fxn age-1	60521.7	121053.0	343.0	1036.3	0.1588	-4.70	0.709	0.079
	0.01	0.1	Linear fxn age-2	60362.7	120735.0	25.0	1054.6	0.1437	-5.27	0.205	0.075
	0.01	0.1	Linear fxn age-3	60354.3	120719.0	9.0	1039.5	0.1582	-4.67	0.147	0.074
	0.01	0.1	Linear fxn size-at-age-1	60522.1	121054.0	344.0	1036.3	0.1588	-4.71	0.741	0.079
	0.01	0.1	Linear fxn size-at-age-2	60361.2	120732.0	22.0	1054.3	0.1439	-5.26	0.215	0.075
	0.01	0.1	Linear fxn size-at-age-3	60349.8	120710.0	0.0	1039.5	0.1580	-4.68	0.156	0.074

Table. 8. Parameter estimates for the von Bertalanffy growth function fit to empirical models and internal to previous stock assessments.

Reference	Sex	L_∞	k	t_0
Lombardi, 2013	F	1251.8	0.1887	-2.16
SEDAR38		1072.1	0.3845	--
SEDAR38U		--	--	--
Garner and Willett, 2026		1339.6	0.1395	-3.44
Lombardi, 2013	M	875.7	0.5111	-0.56
SEDAR38		925.7	0.3515	--
SEDAR38U		--	--	--
Garner and Willett, 2026		1039.5	0.1580	-4.68

FIGURES

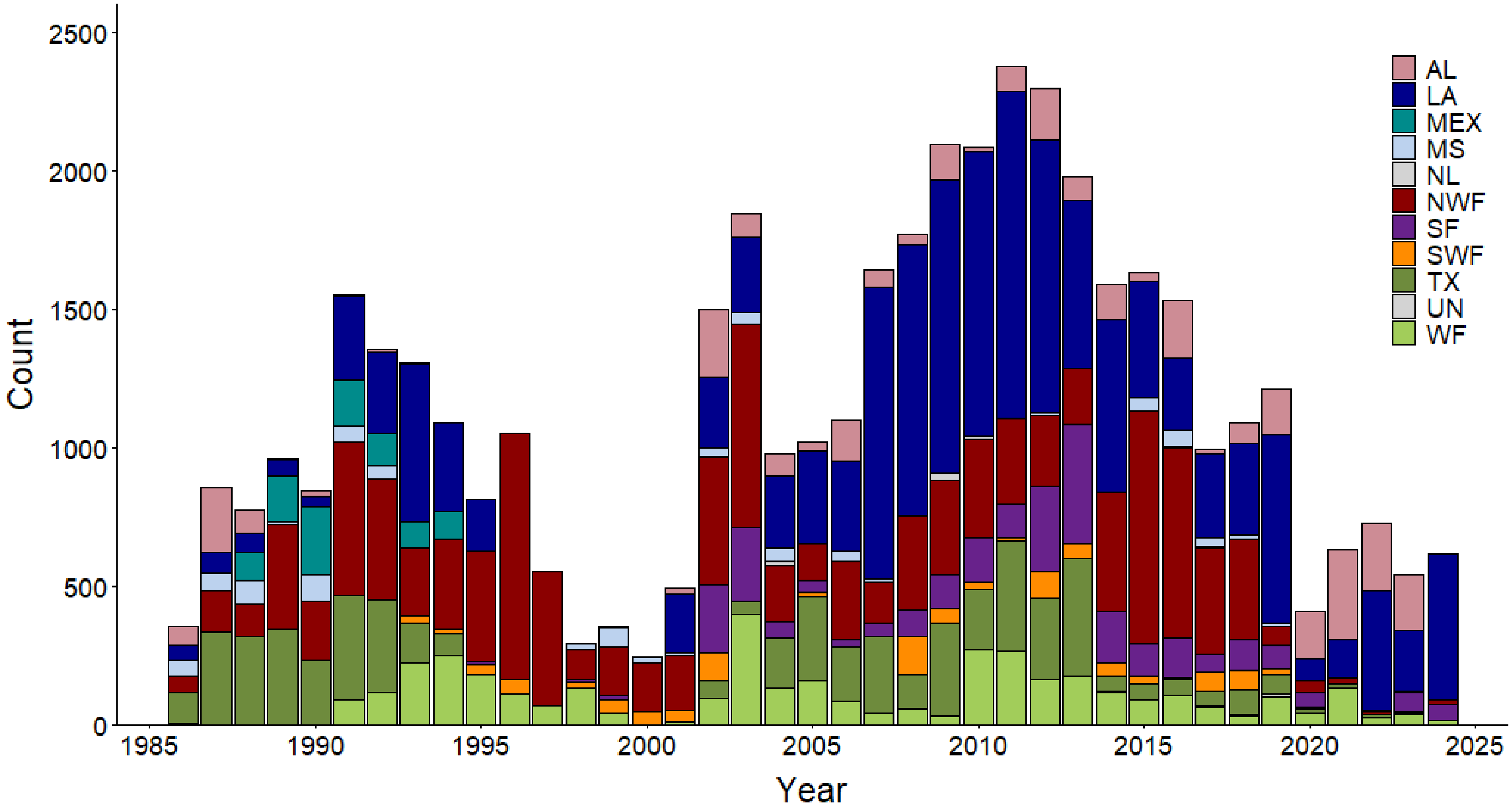

Figure 1. Number of aged samples (count) by mackerel state (Alabama, AL; Louisiana, LA; Mexico, MEX; Mississippi, MS; not landed, NL; northwest Florida, NWF; south Florida, SF; southwest Florida, SWF; Texas, TX; unknown, UN; or west Florida, WF) collected from the Gulf of America from 1986 to 2024. Age samples from the winter mixing zone were excluded from this figure.

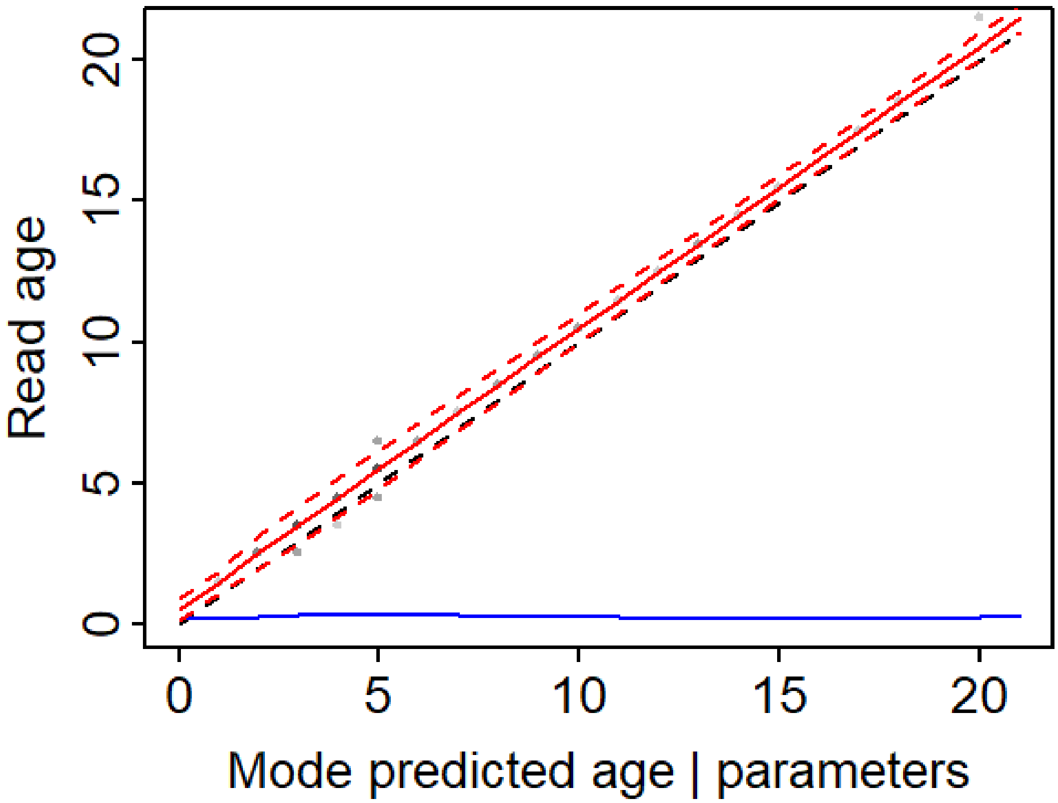

Figure 2. Plots of ageing error-at-age estimates from the best-fit model applied to reader-specific age estimates of the king mackerel otolith reference set. Reader-specific parameters were mirrored to produce a single error-at-age matrix to inform the stock assessment model. The solid red line indicates the mode predicted age, given the best-fit parameters, the dashed red lines indicate 95% CIs about the mode-predicted age, the solid blue line indicates the SD-at-age, and the gray circles indicate ages at each mode-predicted age.

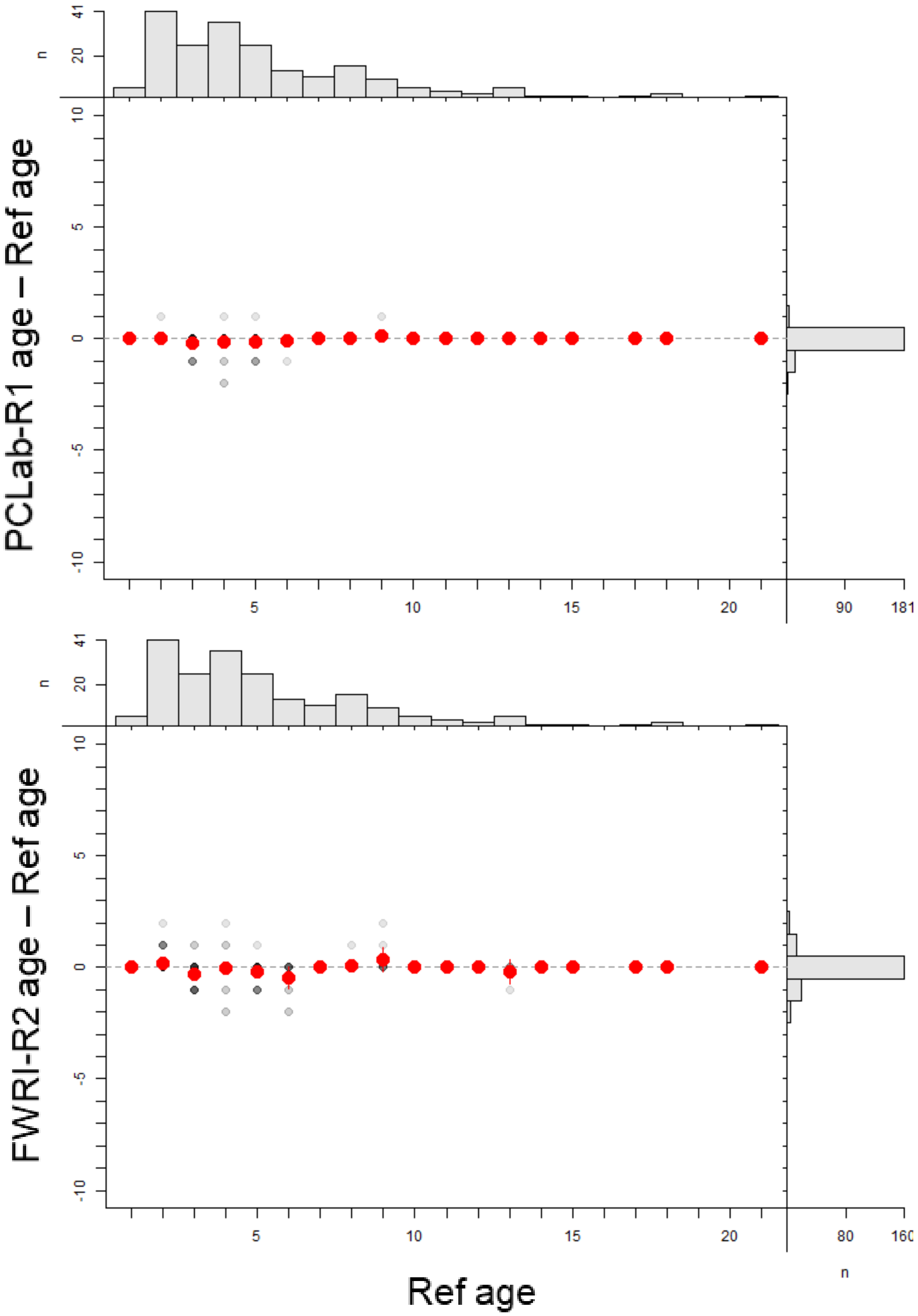

Figure 3. Bland-Altman plots of reference set age estimates for each expert reader. Gray-scaled points indicate age estimates at each reference age (scaled to 1/10 transparency), red circles indicate mean values, and white circles indicate age-specific means that are significantly different from zero (paired t-test; α=0.05). Vertical red lines indicate 95% CI's about the mean. Gray bars indicate the number of observations in each age-class (top of each panel) or age estimate difference (right side of each panel).

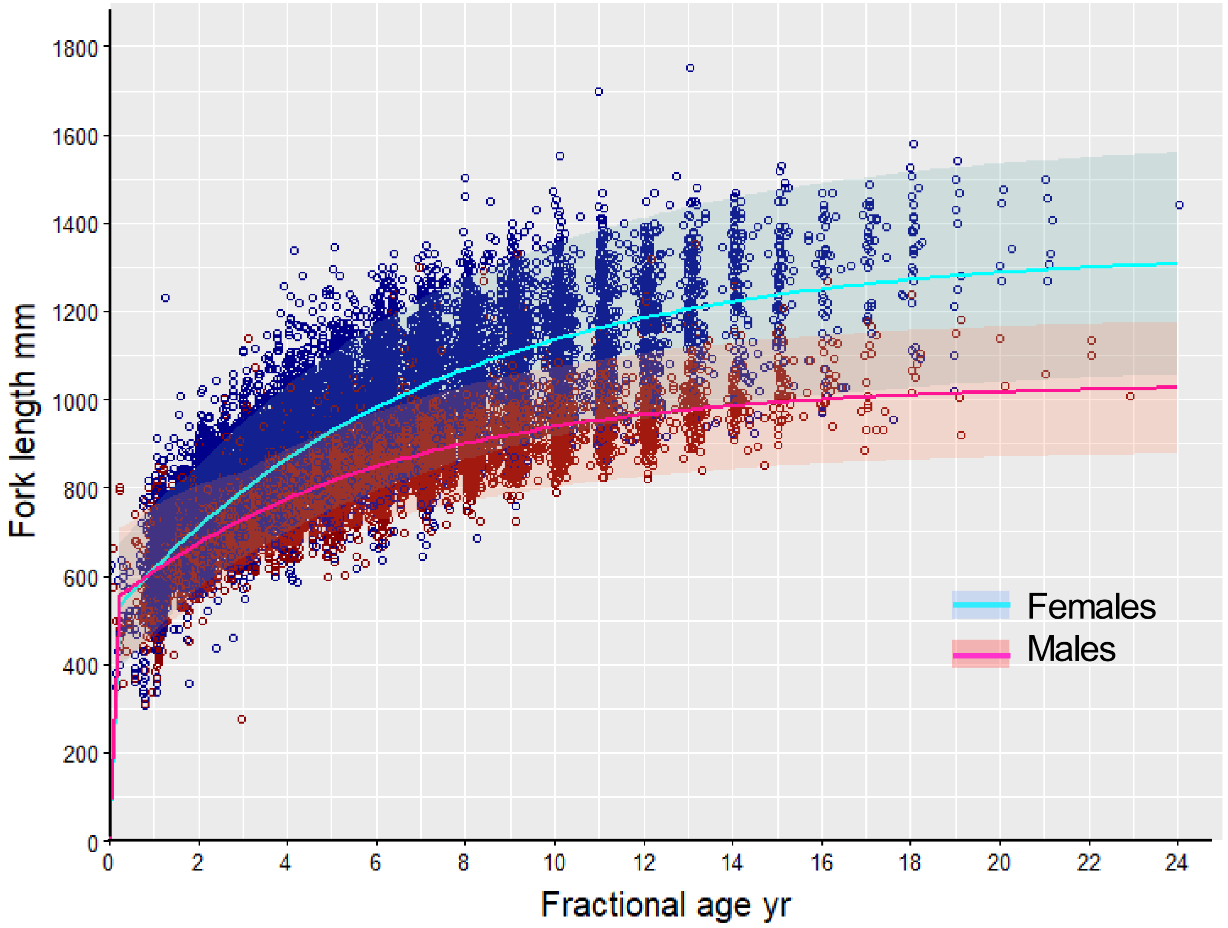

Figure 4. Sex-specific von Bertalanffy growth models estimated for king mackerel length-at-age data. Blue circles indicate length-at-age for females and red circles indicate values for males. Solid lines indicate best-fit parameters from VBG models fit with CV increasing as a linear function of length-at-age for females from A_{min} (0.1) to age-2 ($L_\infty = 1339.6$, $k = 0.1395$, $t_0 = -3.44$, $\sigma^1 = 0.14$, $\sigma^2 = 0.10$) and males from A_{min} to age-3 ($L_\infty = 1039.5$, $k = 0.1580$, $t_0 = -4.68$, $\sigma^1 = 0.16$, $\sigma^2 = 0.07$). Shaded regions indicate sex-specific CV values.

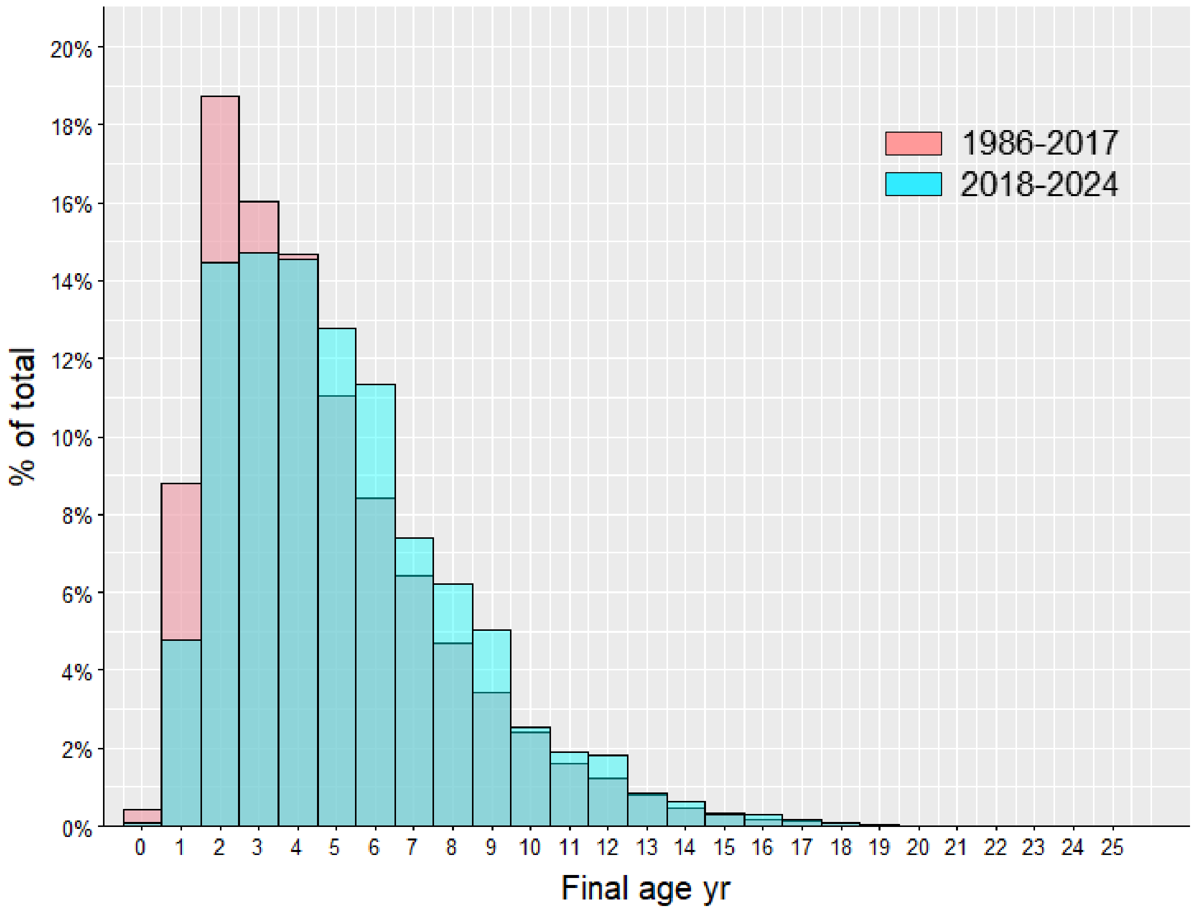

Figure 5. Frequency (% of total) of age samples for new data (2018-2024) versus data presented in SEDAR38U (1986-2017).

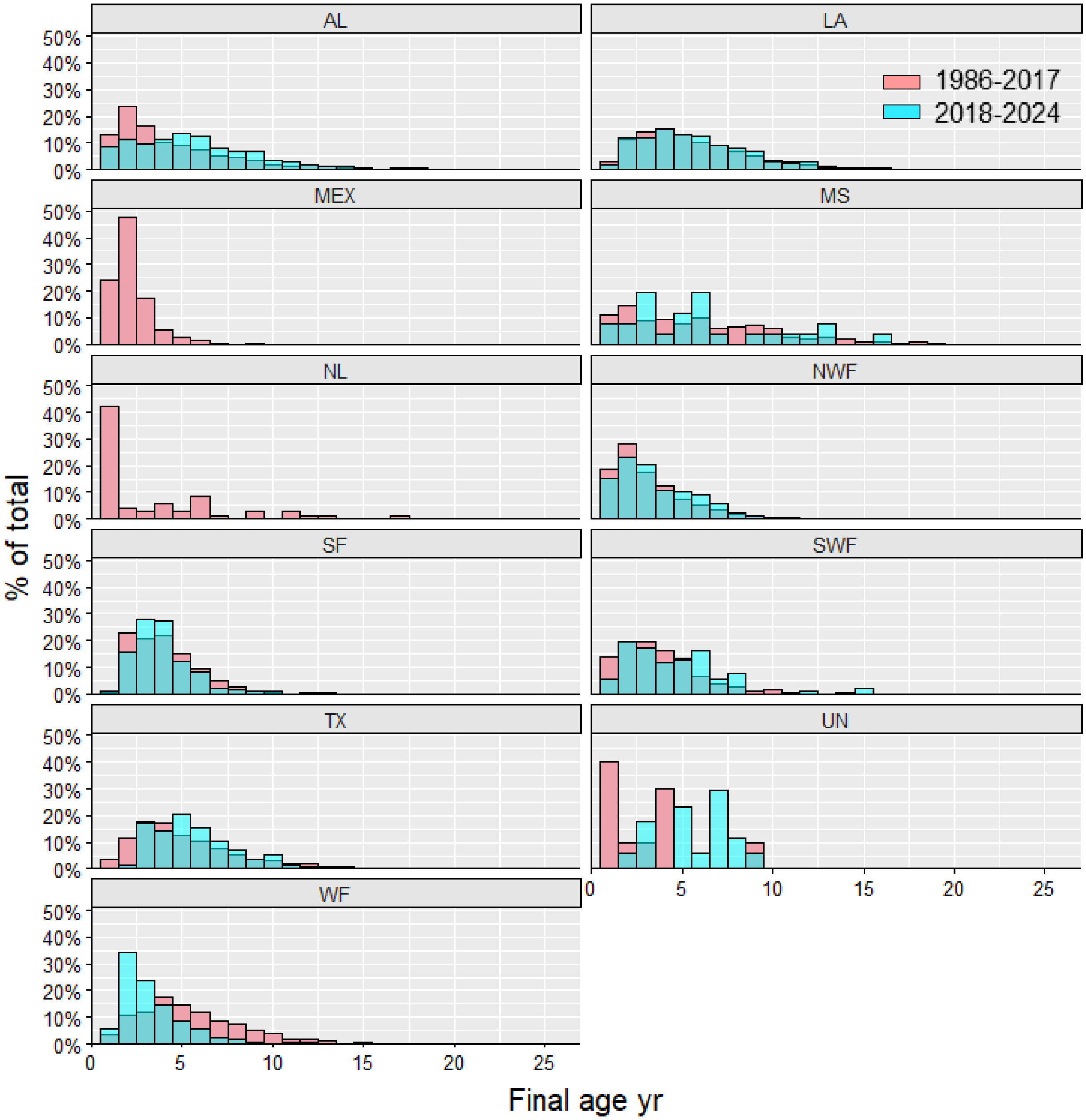

Figure 6. Frequency (% of total) of age samples from new data (2018-2024) versus data presented in SEDAR38U (1986-2017) by mackerel state (Alabama, AL; Louisiana, LA; Mexico, MEX; Mississippi, MS; not landed, NL; northwest Florida, NWF; south Florida, SF; southwest Florida, SWF; Texas, TX; unknown, UN; or west Florida, WF).

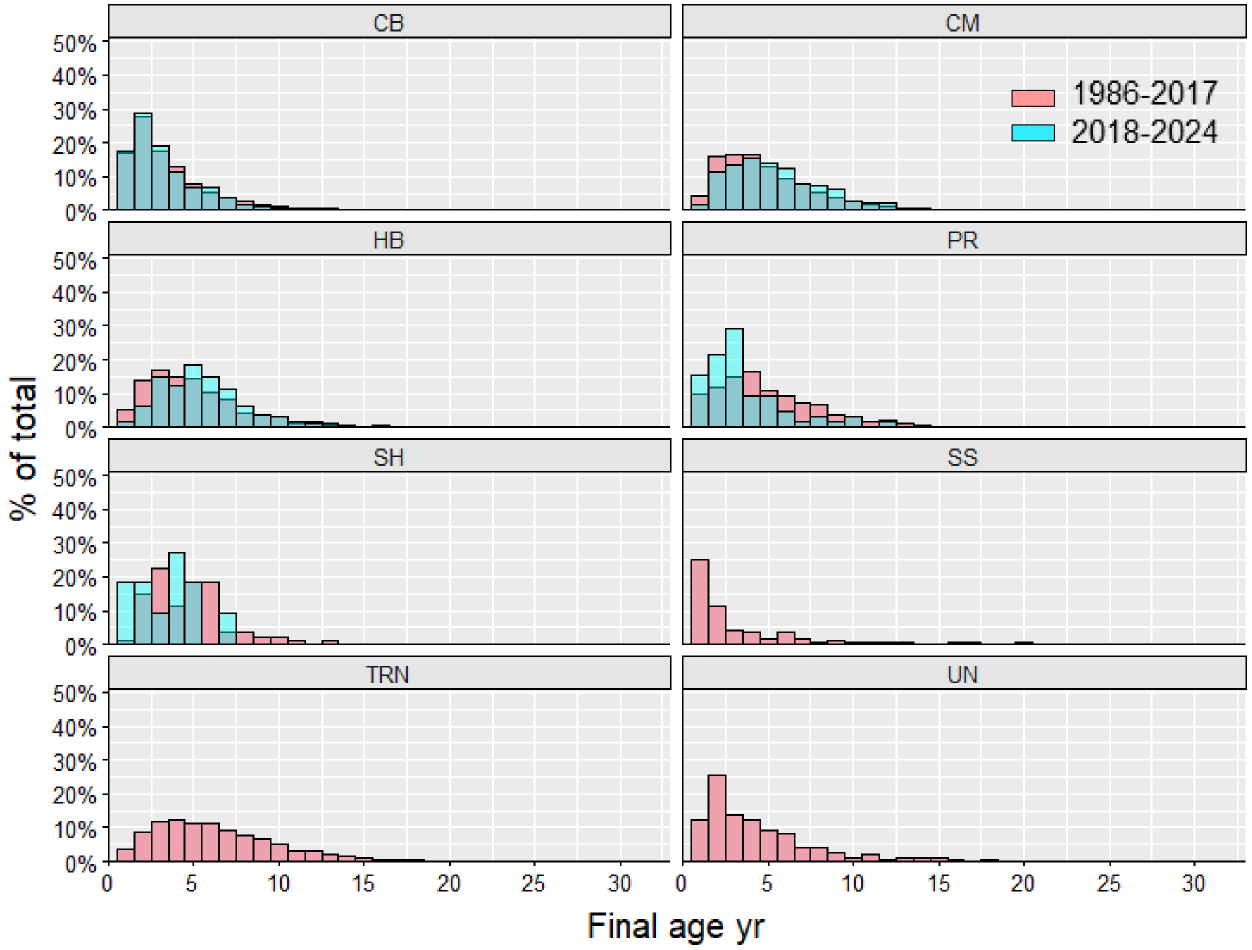

Figure 7. Frequency (% of total) of age samples for new data (2018-2024) versus data presented in SEDAR38U (1986-2017) by fishing mode (charterboat, CB; commercial, CM; headboat, HB; private rec, PR; shore, SH; scientific survey, SS; tournament, TRN; or unknown, UN).

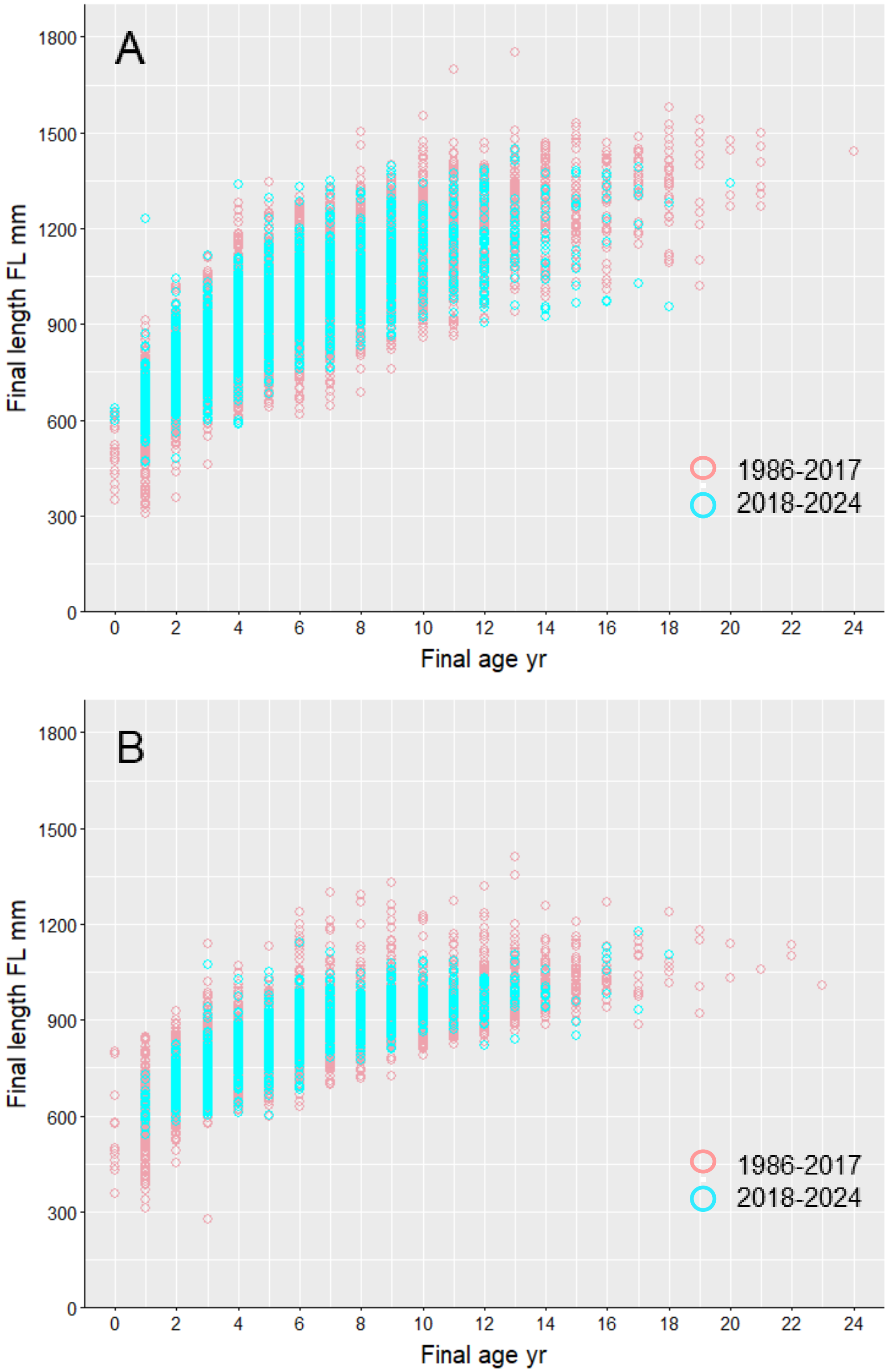

Figure 8. Scatterplots of length vs age for new data (2018-2024) versus data presented in SEDAR38U (1986-2017) by sex (Females, A; Males, B).