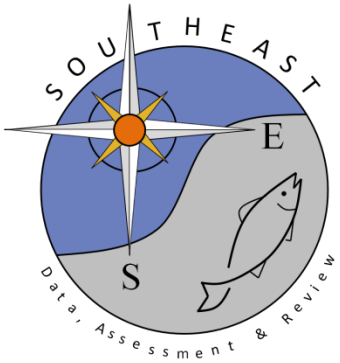
A Review of GAG Grouper (*Mycteroperca microlepis*) Length and Age Data in the Gulf of America, 1977-2025

Naeem Willett and Steven Garner

SEDAR105-WP-14

26 May 2026



Please cite this document as:

Willett, Naeem and Steven Garner. 2026. A Review of GAG Grouper (*Mycteroperca microlepis*) Length and Age Data in the Gulf of America, 1977-2025. SEDAR105-WP-14. SEDAR, North Charleston, SC. 32 pp.

A Review of GAG Grouper (*Mycteroperca microlepis*) Length and Age Data in the Gulf of America, 1977-2025

Naeem Willett and Steven Garner

Submitted:

May 2026

Introduction

This report describes the age and length data submitted to Southeast Data Assessment and Review (SEDAR) for assessment of Gag grouper **(***Mycteroperca microlepis*) in the Gulf of America from 1977 to 2025. Metadata submitted for SEDAR 105 followed the SEDAR Best Practices Template developed in December 2022 (Appendix 1).

Methods

Sample collection

The stock boundary for Gulf of America Gag is all federal and state waters extending northward from the Texas/Mexico border and eastward to the Florida Keys (US1). Samples were collected by federal and state agencies from commercial, recreational, and fishery-independent sources. Commercial (COM) samples were collected through several sampling programs including cooperative research programs (CO-OP), the Florida Fish and Wildlife Research Institute (FWRI and FWRI-MERR), the Galveston Observer Program (GOP), the National Marine Fisheries Service, Panama City Laboratory (PC Lab), the Recreational Fisheries Information Network (RECFIN), the Shark Bottom Longline Observer Program (SBLOP), and the Trip Interview Program (TIP). Recreational samples were collected by the Alabama Marine Resource Division (AMRD), Fisheries Information Network Biological Sampling Program (FIN-BIOSTAT), FWRI (MERR and observer program), Gulf Reef Fish Survey (GRFS), South Region Headboat survey (HB/SRH), Marine Recreational Fishery Statistical Survey (MRFSS), PC Lab, RECFIN, REPBIO, State Reef Fish Survey (SRFS), and TIP. Fisheries independent data were collected by the CO-OP, the Expanded Annual Stock Assessment Project (EASA), Florida

State University, FWRI (FIM, MERR), SRH, NMFS Pascagoula Lab (MS Lab), PC Lab, TIP, United States Geological Survey (USGS), and the University of Texas, Marine Science Institute (UTMSI).

Length and Weight Data

Fish lengths were recorded as maximum total length (MTL; mm), natural total length (NTL; mm), fork length (FL; mm), and/or standard length (SL; mm); final length was taken directly from observed FL when available. If observed FL was not available, FL was converted from other available observed lengths using the morphometric conversions listed in SEDAR 72 (SEDAR, 2019) following the hierarchy: 1) MTL, 2) NTL; or 3) SL. Fish weights were recorded as whole weight (WW, g) and/or gutted weight (GW, g). Final weight was taken directly from observed WW if available. If observed WW was not available, WW was converted from GW if a sample's gutted condition type was "head-on" or "unknown." Discussions during the SEDAR 105 data scoping webinar (March 2026) resulted in the recommendation to update all morphometric equations for SEDAR 105 (Table 1) due to the large increase in number of length and weight samples from the new data period and number of new data years (n = 5) since the previous assessment (terminal year 2020).

Age Data

Otoliths used for age estimation were sectioned with a Hillquist high-speed saw, mounted to clear glass slides, polished, sealed, and stored in slide boxes (Cowan et al. 1995, Fitzhugh et al. 2001). Whole otoliths were viewed under a Zeiss microscope with reflected light following

standard protocols (Johnson et al. 1993; Fitzhugh et al. 2001; GSMFC 2003; NMFS 2008). Samples with difficult to interpret banding patterns and/or thick otoliths were sectioned and re-aged. The number of annuli estimated from the sectioned otolith was always used as the final annuli count estimate. Annuli were enumerated by counting the number of opaque bands visible in each whole otolith using reflected light and margin code (2, 4, or 6) assigned based on the percentage of translucent zone formation relative to the previous annulus (NMFS, 2008). Calendar age was then calculated from the estimate of enumerated annuli, margin code, and capture date (GSMFC 2003; NMFS 2008). Fish from the Southeastern U.S. complete annulus formation by late spring to early summer. Therefore, an annuli count was advanced one year if the fish was captured prior to July 1st and had been assigned an edge code of 6. For example, a Gag captured before July 1st with two complete annuli and a large translucent zone (edge code = 6) would have a calendar age of 3 yrs because that individual would be expected to complete a third annuli prior to its next birthday. For all fish captured on or after July 1, calendar age was equal to annuli count, regardless of the edge code assigned. Fractional age, or biological age, also was assigned to each individual based on the difference between the July 1 birthday and the date of capture. For fish captured prior to July 1, the fraction of the year (number of days after July 1 and before June 30) was subtracted from the calendar age estimate; the fraction of the year at time of capture was added to each fish's calendar age if caught after July 1.

Ageing Error

Ageing error was derived using a reference set created in 2010 of approximately equal numbers of whole and sectioned otoliths (n = 196 total). Reference set samples were selected to represent the "typical" age distribution of Gag in the data as well as the variability in quality (i.e.,

readability differences due to natural variability in banding as well as sectioning methodology) of whole or sectioned otoliths that a reader would encounter. Reader error was examined with Bland-Altman plots and error statistics (e.g., percent agreement, CV, and APE) in the "*FSA*" package (Ogle et al., 2025) in R (R Core Team, 2025).

Age-specific error was estimated in the "*AgeingError*" package (Punt et al. 2008; Thorson et al., 2008) with one reading instance from a previous expert ager and two reading instances (2020 and 2024) from the current expert/primary ager. Age estimates from the three reading instances were converted to tallies of each age-age combination and models fit to the tally data. Candidate models 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), AIC corrected for small sample size (AICc), bayesian information criterion (BIC), and diagnostic plots were used to identify the best-fit model. Models were fit such that a single age-specific error matrix was produced (i.e., reader error was mirrored) for reader 2 for input in the stock assessment model; reader 2 supplied all age estimates for the new data period.

Growth

Gag growth was modeled with the von Bertalanffy growth equation in AD Model builder (Fournier et al. 2012). Probability distributions were specified with the truncated normal distribution to account for length-age pairs presumably missing from the sampled population 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 10 yrs). A second variance parameter was then estimated as a linear function from A_{max} to the maximum observed age of 33 yrs. Variance models for constant SD or CV included only a single variance parameter. Age-at-length data were not weighted.

Natural Mortality

Natural mortality was updated since the previous estimate of *M* provided for SEDAR 72 (2021). The first fully selected age (4 yrs) and the maximum observed age (33 yrs) were specified the same as in SEDAR 72, but the Lorenzen (1996) estimate of age-specific mortality was updated following the Hamel and Cope adjustment (2022) to correct for bias when fitting longevity data reported for other species in Then et al. (2015).

Results and Discussion

A total of n = 69,879 Gag were collected since 1977, with 91.4% (n = 63,890) of those samples providing an estimable age. No ages were estimated for samples collected in 1977 or 1978. A total of n = 7,322 ages were estimated for the new data period (2021 to 2025) in addition to the n = 56,568 ages from historical data period (1979 to 2020) submitted for previous SEDARs (Lombardi et al. 2013; SEDAR 2021). The PC Lab proved 88.1% of the aged samples (Table 2) with the nearly all aged samples (95.0%) collected in Florida (n= 60,708). Most samples were collected from the commercial sector (74.9%), with 18.8% from collected from the recreational fleet and 5.9% from fisheries independent sources (Table 3). Only 0.4% of samples were collected from unknown sources. Samples from the commercial sector were predominantly

taken from fish captured with handline (57.5%) or bottom longline (39.1%), but a small percentage were taken with spears (2.6%) or vertical longline (0.5%) gear (Table 4).

Length frequencies of Gag indicated that larger individuals comprised a much higher percentage of the aged samples in the new data period compared to all previous years, especially samples from REC or FI sources (Figure 1). Age frequencies indicated that these fish were predominantly 4 to 6 years of age (Figure 2). Age estimates ranged from 0 to 33 years with age-5 fish comprising the greatest individual percentage 21.49%. Fish greater than age-20 were relatively rare, comprising less <1% of all aged samples. Although variable between years, median length and age across all data sources have remained fairly stable since 1991 at around 700-800 (Figure 3) mm and 4-7 yrs (Figure 4). Older individuals were collected in low numbers throughout the time series. Samples from the COM fishery had the highest mean (± SD) age (6.09 ± 0.01, Table 5), length (772.57 ± 0.60, Table 6), and weight (6806.3 ± 17.71, Table 7) compared to samples collected from REC or FI sources, which were both very similar.

Ageing Error

Reader precision was consistently high between reference set reads with percent agreement values of 70.8% and 63.8%. Average percent error was 3.2 and 4.4% between reads. The best-fit model for age-specific error fit modal ages with a constant CV for both the expert and primary reader as well as both instances of the primary reader's reference set age estimates (Table 8, Figure 5).

Growth

A von Bertalanffy growth model with the CV estimated as a function of length was the best-fit model based on AICc values (Table 9, Model 5). The best-fit model estimated L_∞ to be 1215.6 mm, which was 106.5 mm smaller than what was estimated in SEDAR 33 and 56.4 mm smaller than in SEDAR 72. Estimated *k* parameter values were very similar between SEDAR 72 (0.141) and SEDAR 105 (0.143). Age-at-length data indicate that length increases fairly linearly through age-5 then begins to slow until reaching asymptotic length of 1215.6 mm occurring around age 20 (Figure 6). Unlike SEDAR 72, the growth equation used in SEDAR 105 was estimated using a linear interpolation to a very young age (0.1 yrs) and proceeded to follow the VBGF function thereafter, which allowed for more reasonable fits to the data since few fish below 200 mm FL have been observed. Model variance was fit with two separate CV parameters, one corresponding to the variance as a linear function of age from the min age (0.1 yrs) to age-7 yr, and the second from age-7 to the max age (33 yrs).

References

Cowan, J. H., Shipp, R. L., Bailey, H. K., and D. W. Hawick. 1995. Procedure for rapid processing of large otoliths. Trans. Am. Fish. Soc. 124: 280-282.

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.

Fitzhugh, G. R., Lombardi-Carlson, L. A., and N. M. Evou. 2001. Gag (*Mycteroperca microlepis*) age-structure from the eastern Gulf of Mexico:1991-2000. National Marine Fisheries Service Panama City Lab, Contribution 01-02.

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.

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.

Hamel, O.S., and J.M. Cope. 2022. Development and considerations for application of a longevity-based prior for the natural mortality rate. Fisheries Research. 256: 106477. doi:10.1016/j.fishres.2022.106477

Johnson, A.G., Collins, L.A., and J.J. Isley. 1993. Age-size structure of gag, *Mycteroperca microlepis*, from the northeastern Gulf of Mexico. Northeast Gulf Sci. 13: 59-63.

Lombardi, L.A., G.R. Fitzhugh, and B. Barnett. 2013. Age, length, and growth of gag (*Mycteroperca microlepis*) from the northeastern Gulf of Mexico: 1978-2012. SEDAR33-DW21. SEDAR, North Charleston, SC. 29 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.

Ogle, D.H., J.C. Doll, A.P. Wheeler, A. Dinno. 2025. FSA: Simple Fisheries Stock Assessment Methods. R package version 0.10.0. https://CRAN.R-project.org/package=FSA

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). 2019. SEDAR72 Gulf of Mexico Gag Grouper Stock Assessment Report. SEDAR, 4055 Faber Place Drive, North Charleston, SC. 318 pp.

Then, A., J.M. Hoenig, N.G. Hall, D.A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science. 72(1): 82-92. doi:10.1093/icesjms/fsu136

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.

Tables

Table 1. Meristic (maximum total length – MaxTL, natural total length – NatTL, fork length – FL, standard length – SL, whole weight – WW, and gutted weight – GW) conversion equations for Gulf Gag collected from 1977-2024. Conversions with gutted weights only included samples with a "head on" or unknown condition type.

		S72	S105					S72		S105			
Reference	**EQ**	**n**	**n**	**Δ**	**X**		**Y**	**a**	**b**	**a**	**b**	**units**	**Update Eq**
SEDAR33	$Y = a*X^b$	9,793	29,024	19,231	FL	->	GW	7.28E-06	3.08	8.22E-06	3.07	mm, g	Yes
SEDAR33	Y = a*Xb	5,238	11,721	6,483	FL	->	WW	1.17E-05	3.02	1.03E-05	3.04	mm, g	Yes
SEDAR33	Y = a + b*X	4,789	7,162	2,373	MaxTL	->	FL	1.07	0.97	1.15	0.97	mm	Yes
SEDAR33	Y = a*Xb	4,266	6,059	1,793	MaxTL	->	WW	1.05E-05	3.03	8.56E-06	3.05	mm, g	Yes
SEDAR33	Y = a*Xb	540	581	41	MaxTL	->	GW	7.31E-06	3.07	6.89E-06	3.08	mm, g	Yes
SEDAR33	Y = a*Xb	1,934	4,602	2,668	NatTL	->	WW	1.36E-05	2.99	1.42E-05	2.97	mm, g	Yes
SEDAR33	Y = a*Xb	40	479	439	NatTL	->	GW	3.50E-08	3.85	5.88E-06	3.10	mm, g	Yes
SEDAR33	Y = a + b*X	1,599	2,025	426	NatTL	->	FL	13.15	0.96	13.17	0.96	mm	Yes
NMFS 1981	Y = a*X	--	152	--	GW	->	WW	--	1.18	--	1.057	none	Yes
SEDAR105	Y = a + b*X	--	676	--	SL	->	FL	--	--	26.18	1.11	mm	Yes

Table 2. Number of gag age samples by data provider (Florida Fish and Wildlife Research Institute, FWRI; Gulf Fisheries Information Network, GulfFIN; and NMFS Panama City Lab, AGR/BSD) from 1977 to 2025 in the Gulf of America.

Year	FWRI	GulfFIN	PC Lab - AGR	PC Lab - BSD	Total
1979			548		548
1980			150		150
1981			64		64
1983			3		3
1986			1		1
1987			5		5
1988			27		27
1989			14		14
1990			12		12
1991			357		357
1992			493		493
1993			827		827
1994			754		754
1995			657		657
1996			942		942
1997			270		270
1998			349		349
1999			520		520
2000			645		645
2001			1,820		1,820
2002			2,328		2,328
2003			2,051		2,051
2004			2,583		2,583
2005			1,934		1,934
2006	35		1,291		1,326
2007	52	10	1,458		1,520
2008	117		1,545		1,662
2009	276	3	2,346		2,625
2010	379	2	2,748		3,129
2011	89	1	448	1,962	2,500
2012	129	12	382	2,040	2,563
2013	192	1	374	3,022	3,589
2014	16	2	497	2,730	3,245
2015	53	440	100	2,189	2,782
2016	342	206	54	3,001	3,603
2017	344	246	26	2,623	3,239
2018	203	372	38	2,298	2,911
2019	216	386	95	2,057	2,754
2020	432	292	31	1,011	1,766
2021	361	502	97	1,126	2,086
2022	372	342	67	1,741	2,522
2023	1,047	48	24	926	2,045
2024	65	17		587	669
%Total	7.39	4.51	45.35	42.75	100.00
Total	4,720	2,882	28,975	27,313	63,890

Table 3. Number of aged samples by collection year and fishery (commercial, COM; fishery independent, FI; recreational, REC; or Unknown, UN).

Year	COM	FI	REC	UN	Total
1979			504	44	548
1980		2	147	1	150
1981	54		10		64
1983	3				3
1986			1		1
1987			5		5
1988			27		27
1989			14		14
1990			12		12
1991	217		135	5	357
1992	88	3	402		493
1993	430		397		827
1994	444	4	306		754
1995	315	27	315		657
1996	257	104	581		942
1997	42		228		270
1998	210	7	122	10	349
1999	390	18	112		520
2000	570	13	62		645
2001	1612	37	171		1,820
2002	1909	17	400	2	2,328
2003	1640	61	350		2,051
2004	2378	66	139		2,583
2005	1606	67	261		1,934
2006	1176	50	100		1,326
2007	1346	63	111		1,520
2008	1186	134	266	76	1,662
2009	1839	384	402		2,625
2010	1917	397	815		3,129
2011	1970	185	345		2,500
2012	2109	134	320		2,563
2013	3103	196	290		3,589
2014	2727	26	492		3,245
2015	2209	53	493	27	2,782
2016	3046	328	200	29	3,603
2017	2601	343	257	38	3,239
2018	2253	179	428	51	2,911
2019	2002	209	539	4	2,754
2020	1126	244	396		1,766
2021	1153	310	623		2,086
2022	2022	30	470		2,522
2023	1297	31	717		2,045
2024	631	19	19		669
%Total	74.9%	5.9%	18.8%	0.4%	100.0
Total	47,878	3,741	11,984	287	63,890

Table 4. Samples by fishery (commercial, COM; recreational, REC; or fishery-independent, FI) and gear group code (handline, HL; bottom longline, LL; seine net, SN; spearfishing, SP; trap, TR; trawl, TW; or vertical longline, VL). Samples collected with unknown gear types not shown.

	COM								REC			FI							
Year	**HL**	**LL**	**SP**	**TR**	**TW**	**UN**	**VL**	**Total**	**HL**	**SP**	**Total**	**HL**	**LL**	**SN**	**SP**	**TR**	**TW**	**VL**	**Total**
1979									504		504								
1980									147		147								2
1981	54							54	10		10								
1983						3		3											
1986									1		1								
1987									5		5								
1988									27		27								
1989									14		14								
1990									12		12								
1991	210	7						217	125	10	135								
1992	66	22						88	378	24	402	3							3
1993	417	12		1				430	386	11	397								
1994	439	3	2					444	302	4	306	2				2			4
1995	284	31						315	315		315	26							27
1996	197	57		3				257	581		581	104							104
1997	34	6				2		42	228		228								
1998	106	101	2	1				210	122		122					7			7
1999	145	243		2				390	112		112	14	2			2			18
2000	387	177		6				570	62		62	12				1			13
2001	745	867						1,612	163	8	171	24	12			1			37
2002	809	1,085		15				1,909	368	32	400	8	2		3	4			17
2003	520	1,117		3				1,640	338	12	350	38	5		2	16			61
2004	894	1,484						2,378	139		139	24	9		9	24			66
2005	740	857	9					1,606	261		261	17				50			67
2006	641	534		1				1,176	97	3	100	1		23		16	10		50
2007	408	936				2		1,346	88	23	111	3	1	7	1	7	44		63
2008	680	506						1,186	262	4	266			78		18	38		134
2009	1,027	773					39	1,839	347	55	402	175	4	88		36	81		384
2010	799	883	21			6	208	1,917	745	70	815	288	2	34		18	49	5	397
2011	1,436	518	11				5	1,970	343	2	345	138	14	6	2	18	7		185
2012	1,616	456	34				3	2,109	288	32	320	110		15		7	2		134
2013	2,222	803	78					3,103	220	70	290	171	6	9		5	2	3	196
2014	1,523	999	205					2,727	459	33	492	1	4	6		6	8	1	26
2015	973	984	248			4		2,209	483	9	493	33		2		11	7		53
2016	1,755	1,195	94		2			3,046	190	10	200	320	2	1		5			328
2017	1,563	903	135					2,601	241	14	257	324	1	5		9	2	2	343
2018	1,425	700	128					2,253	424	2	428	168	2			7	2		179
2019	1,345	624	33					2,002	529	8	539	207	1				1		209
2020	897	87	127		13	2		1,126	332	50	396	242		2					244
2021	786	192	97			78		1,153	608	8	623	310							310
2022	1,240	768	14					2,022	461	9	470	28	1				1		30
2023	671	623	3					1,297	683	34	717	30	1						31
2024	480	142	9					631	18	1	19	19							19
%Total	57.5	39.0	2.6	0.1	0.0	0.2	0.5	100.0	95.3	4.5	100.0	75.9	1.8	7.4	0.5	7.2	6.8	0.3	100.0
Total	27,534	18,695	1,250	32	15	97	255	47,878	11418	538	11984	2840	69	276	17	270	254	11	3741

Table 5. Comparison of mean final age (yr) by fishery (commercial, COM; fishery independent, FI; recreational, REC; or Unknown, UN) with sample size (N), standard deviation (SD) and confidence interval (CI).

Fishery	N	Final Age	SD	SE	CI
COM	47878	6.09	2.62	0.012	0.024
FI	3741	4.52	3.14	0.051	0.101
REC	11984	4.30	1.93	0.018	0.035
UN	287	3.98	2.33	0.137	0.270

Table 6. Comparison of mean final length (FL mm) by fishery (commercial, COM; fishery independent, FI; recreational, REC; or Unknown, UN) with sample size (N), standard deviation (SD) and confidence interval (CI).

Fishery	N	Final Length	SD	SE	CI
COM	47856	772.57	131.0	0.60	1.17
FI	3708	625.51	226.3	3.712	7.29
REC	11968	660.21	113.0	1.03	2.03
UN	242	623.99	190.7	12.26	24.15

Table 7. Comparison of mean final weight (whole, g) by fishery (commercial, COM; fishery independent, FI; recreational, REC; or Unknown, UN) with sample size (N), standard deviation (SD) and confidence interval (CI).

Fishery	N	Final Weight	SD	SE	CI
COM	47869	6806.3	3887.8	17.769	34.828
FI	3712	4323.3	3775.9	61.976	121.51
REC	11972	4184.1	2691.7	24.601	48.221
UN	242	4245.3	3385.1	217.61	428.65

Table 8. Age-specific estimates of standard-deviation (SD) for the primary ager. True age is the consensus age from the Gag reference set (n = 196). Estimates were derived from two separate reading instances along with one reading instance from a separate expert reader who did not provide any production ages during the new data period.

True_Age	0	1	2	3	4	5	6	7	8	9	10
SD	0.15	0.15	0.29	0.44	0.58	0.73	0.87	1.02	1.16	1.31	1.45
True_Age		**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SD		1.60	1.74	1.89	2.03	2.18	2.32	2.47	2.61	2.76	2.90

Table 9. Parameter estimates from various von Bertlanffy growth model parameterizations for Gag length-at-age data fit in AD Model Builder.

SEDAR	#	Model	Obj Fxn	AICc	ΔAICc	L_∞	k	t_0	σ_1	σ_2
33		Linear fxn age (age-1) (internal)	--	--	--	1322.1	0.1070	-1.220	--	--
72		Constant sigma* (external)	--	--	--	1272.0	0.1412	-0.331	--	--
105	1	Constant sigma*	343356	686720	260	1224.8	0.1391	-0.947	76.30	--
105	2	Constant CV*	NaN	--	--	--	--	--	--	--
105	3	Linear fxn age (age-1)*	345276	690562	4102	1168.1	0.1529	-0.924	0.16	0.11
105	4	Linear fxn age (age-6)*	343340	686689	229	1205.8	0.1460	-0.797	0.22	0.09
105	5	Linear fxn age (age-7)*	343225	686460	0	1215.6	0.1427	-0.840	0.20	0.08
105	6	Linear fxn age (age-8)*	343275	686560	100	1219.5	0.1412	-0.878	0.18	0.08
105	7	Linear fxn age (age-9)*	343352	686714	254	1221.6	0.1403	-0.904	0.17	0.07
105	8	Linear fxn age (age-10)*	343421	686852	392	1223.0	0.1398	-0.923	0.16	0.07
105	9	Linear fxn size-at-age (age-1)*	377546	755102	68642	662.5	0.0439	-1.953	1.98	1.75
105	10	Linear fxn size-at-age (age-6)*	343411	686831	371	1203.9	0.1466	-0.791	0.26	0.09
105	11	Linear fxn size-at-age (age-7)*	343254	686518	58	1212.7	0.1438	-0.821	0.24	0.08
105	12	Linear fxn size-at-age (age-8)*	343242	686494	34	1216.2	0.1425	-0.848	0.22	0.08
105	13	Linear fxn size-at-age (age-9)*	343259	686528	68	1218.0	0.1419	-0.866	0.21	0.07
105	14	Linear fxn size-at-age (age-10)*	346383	692777	6317	1339.6	0.0982	-2.457	0.12	0.09

*size-modified

Figures

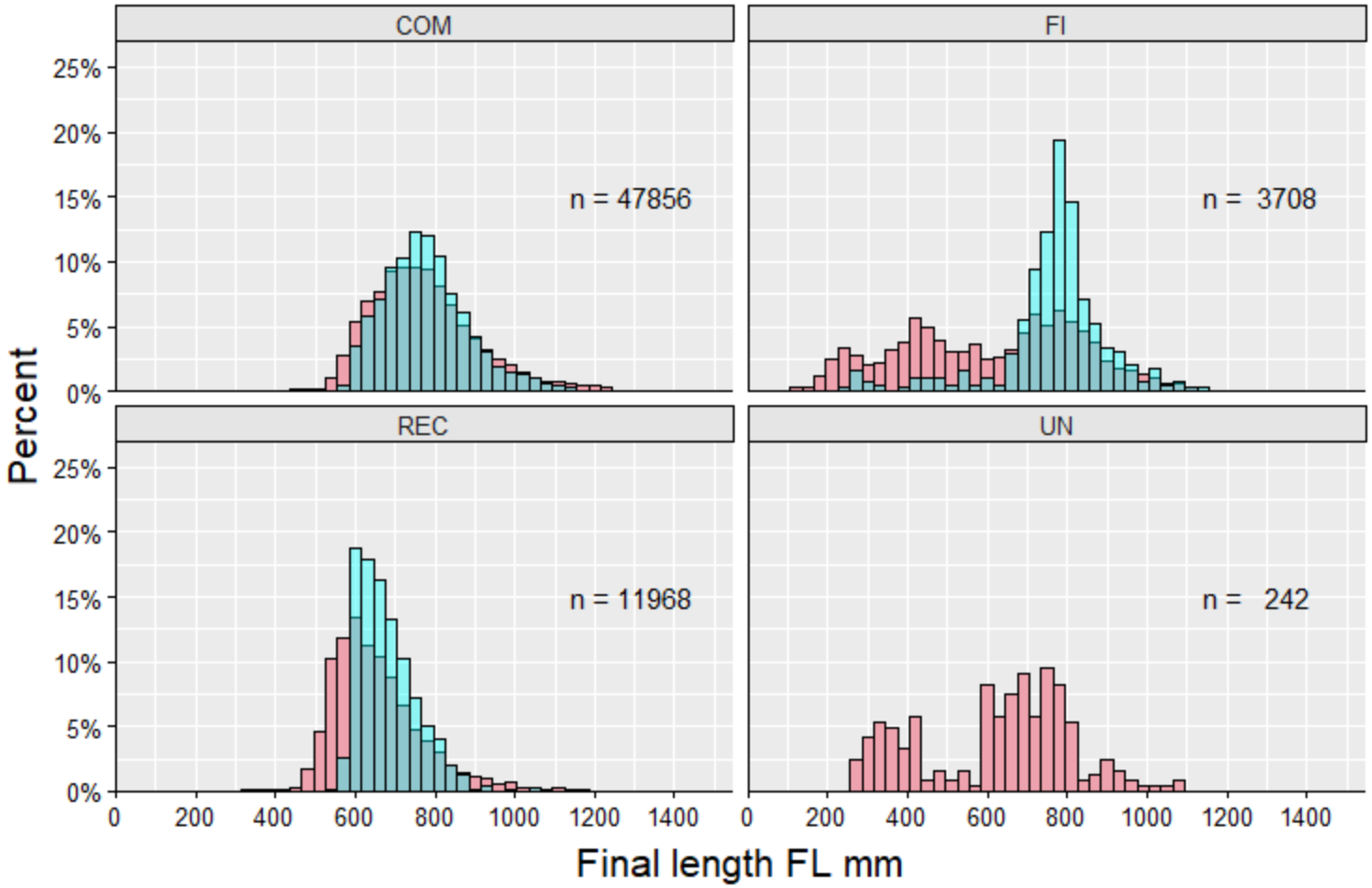


Figure 1. Length frequency (% of total) of gag age samples by fishery from the old (1979-2020; salmon bars) vs new (2021-2024; cyan bars) data periods for samples collected from the Gulf of America.

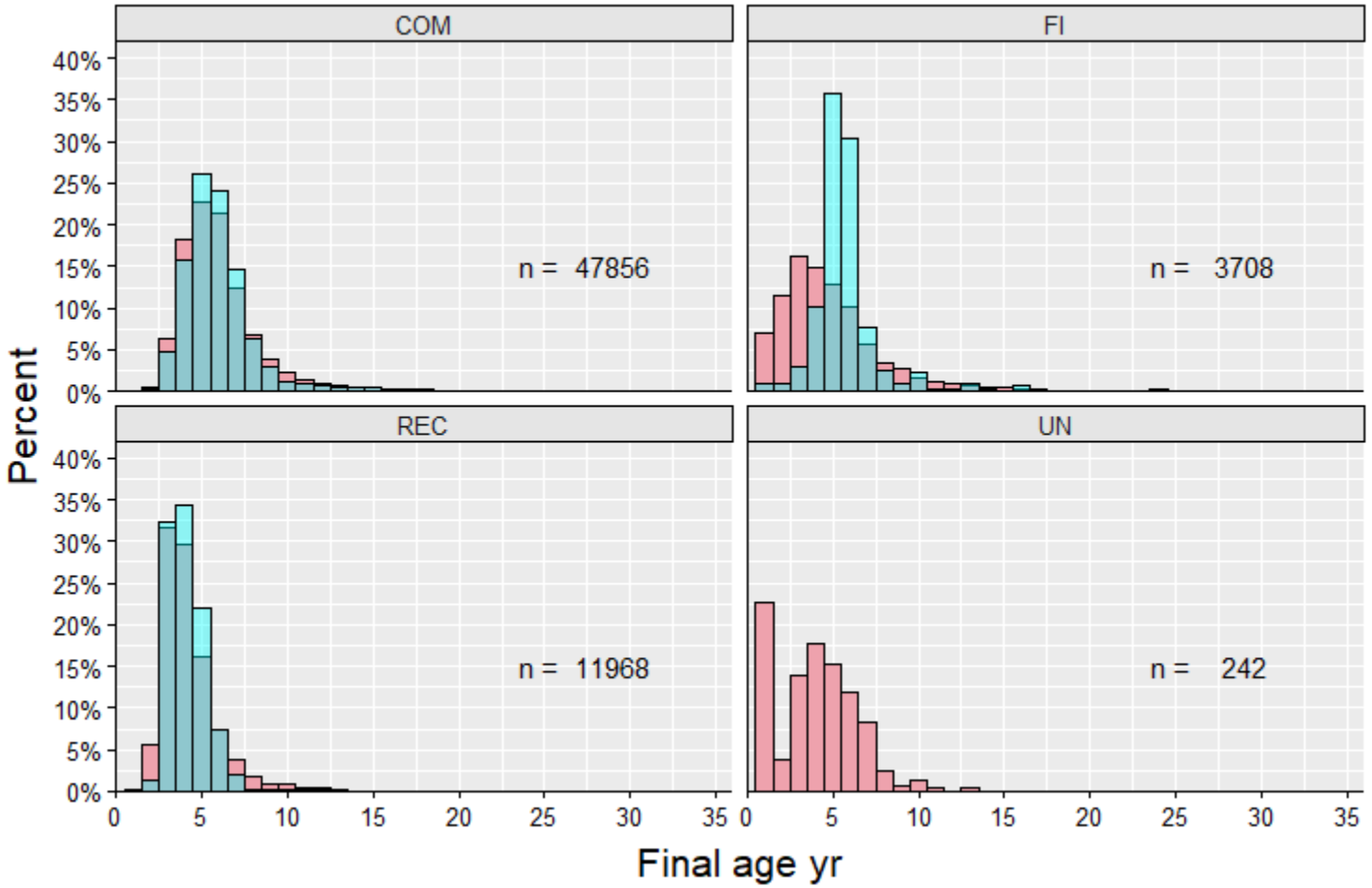


Figure 2. Age frequency (% of total) of aged samples by fishery for the old (1979-2020; salmon bars) vs new (2021-2024; cyan bars) data periods for gag collected from the Gulf of America.

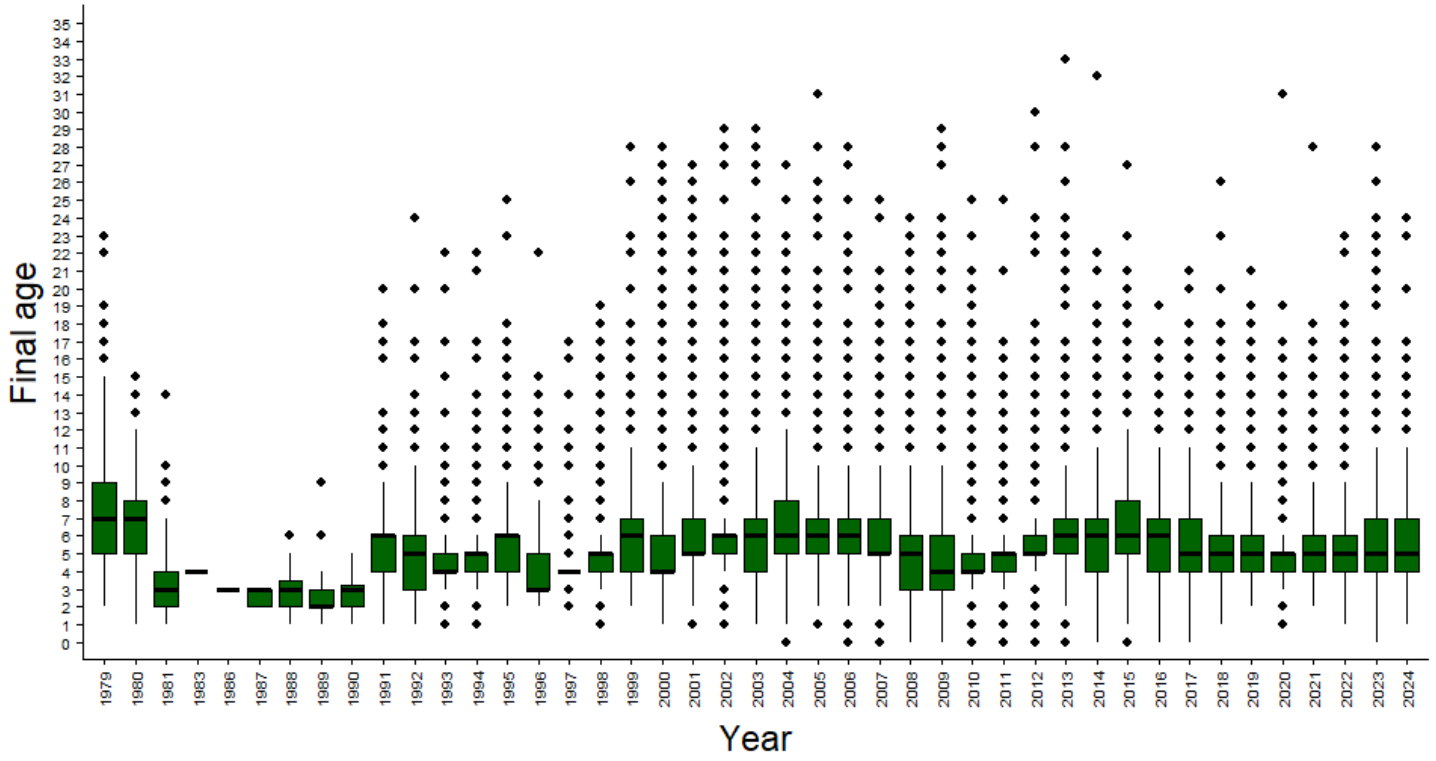


Figure 3. Boxplots of final age by year for Gag collected from 1979 to 2024. Green boxes indicate the upper and lower quartile range (25% and 75%), black horizontal bars indicate median values, vertical lines indicate ±1.5*IQR, and black diamonds indicate values falling outside the 1.5*IQR.

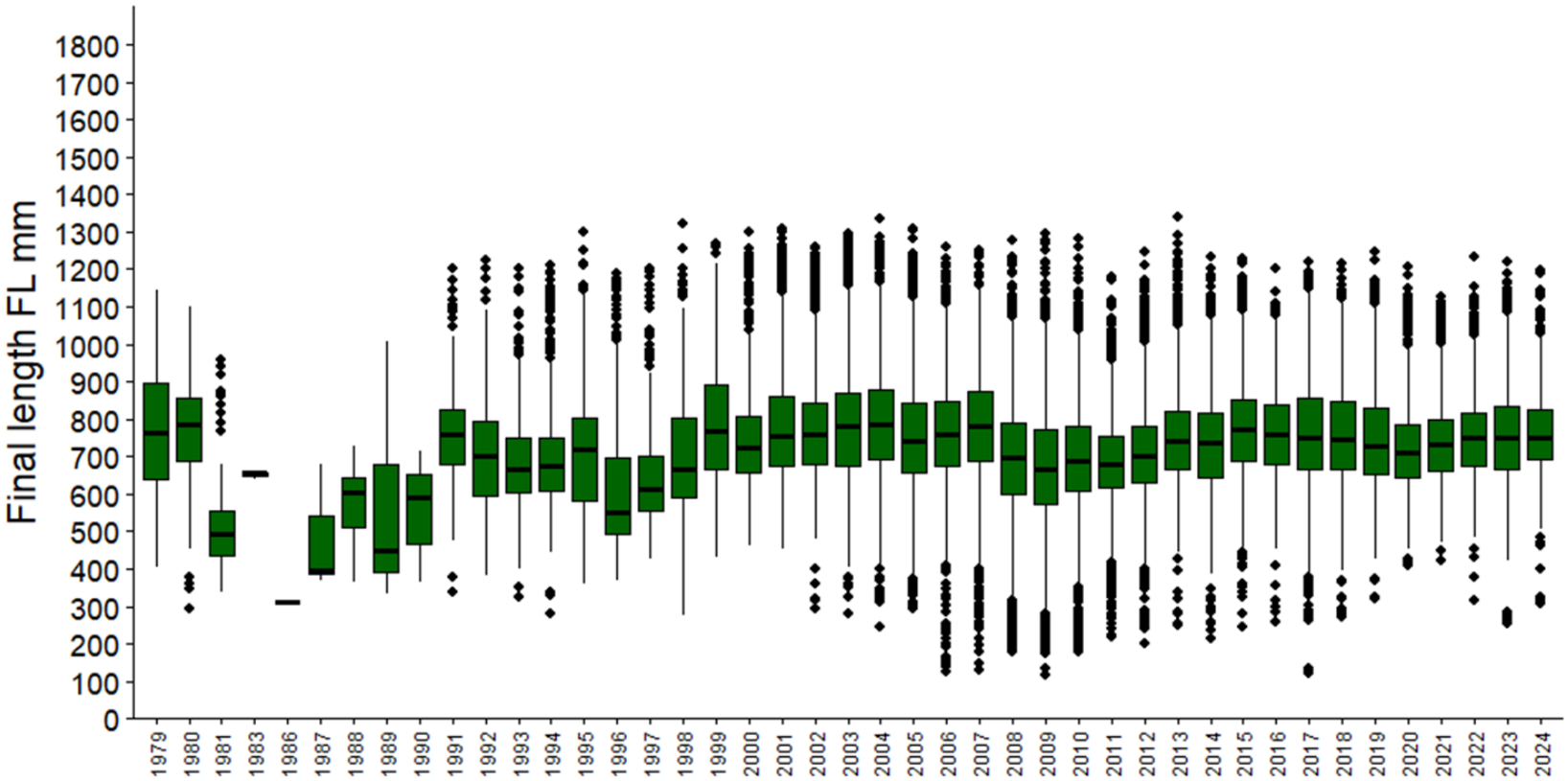


Figure 4. Boxplots of final length (FL mm) by year for Gag collected from 1979-2024. Green boxes indicate the upper and lower quartile range (25% and 75%), black horizontal bars indicate median values, vertical lines indicate ±1.5*IQR, and black diamonds indicate values falling outside the 1.5*IQR.

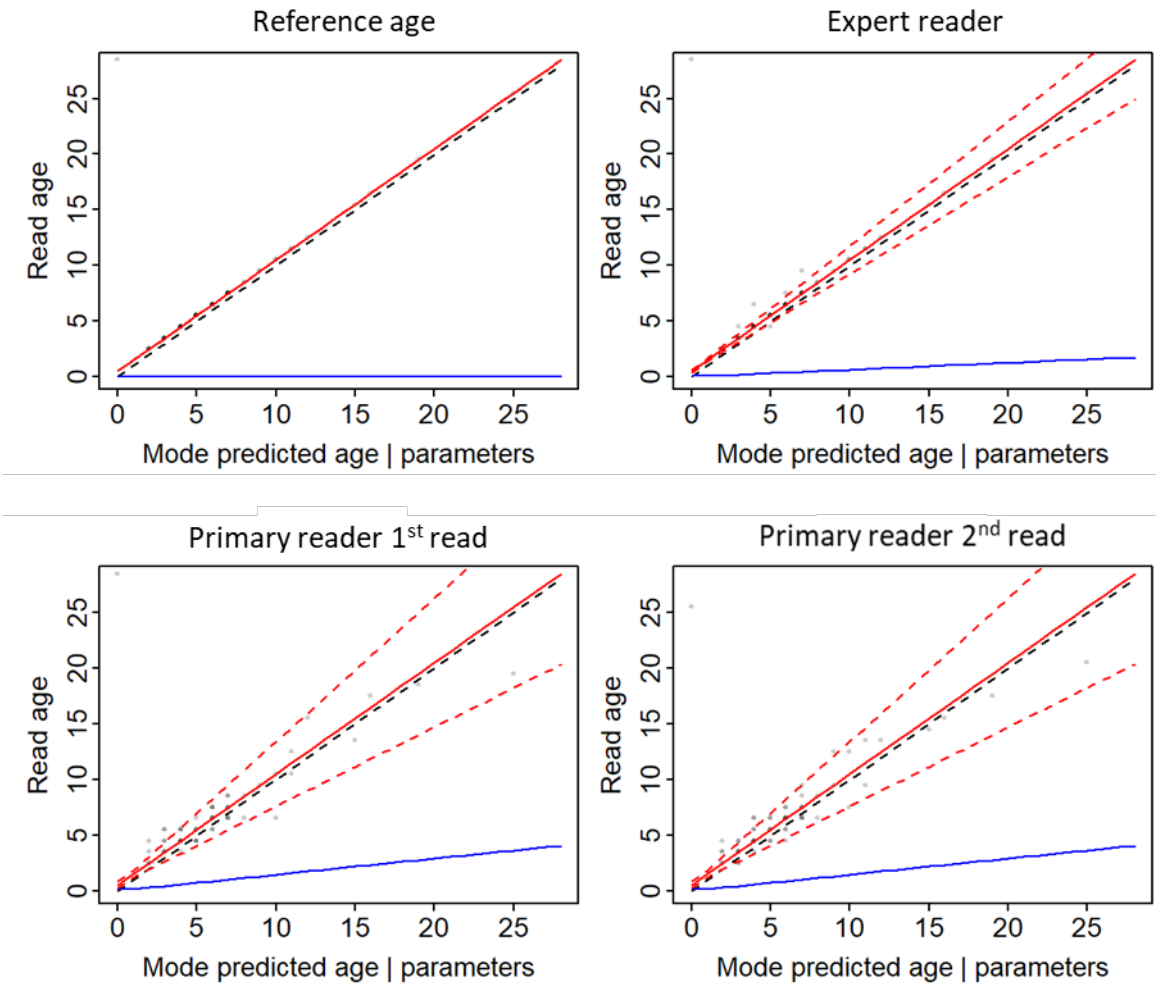


Figure 5. Reader precision plots for expert readers and primary readers 1 and 2 vs reference ages given the variance parameters estimated in the ageing error model for Gag grouper. Gray points indicate observed ages, the black dashed line indicates the 1:1 line of agreement, the red solid line indicates the expected age, red dashed lines indicate the 95% CI for expected ages, and the blue line indicates the SD-at-age. The reference set was assumed to be unbiased but with error. The two primary readers, acting as a single ager providing data were assigned mirrored parameter estimates during the model estimation, hence identical plots for readers 1 and 2.

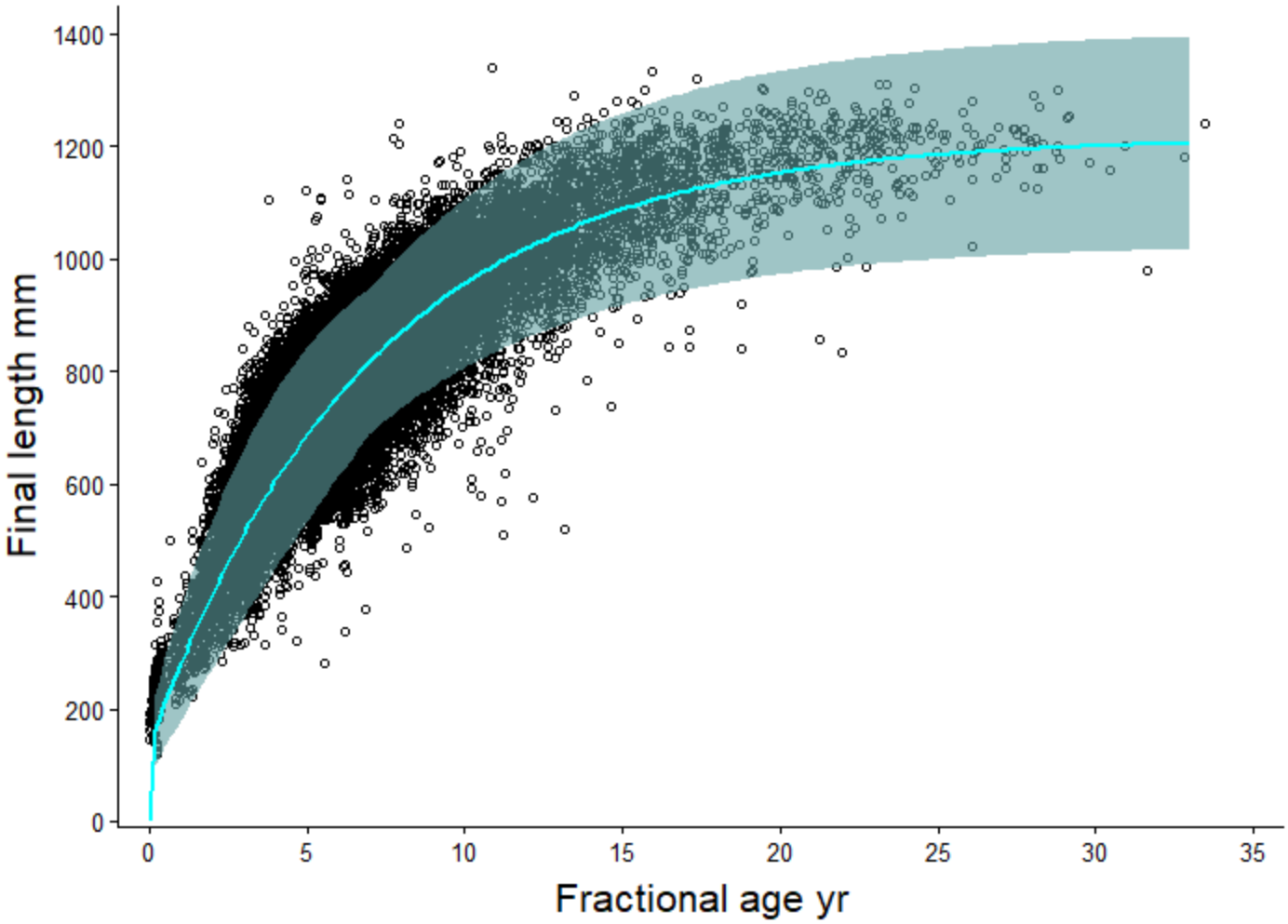


Figure 6. Scatterplot of final length (fork length, mm) vs fractional age (biological age, yr) of Gag collected from the Gulf of America from 1979 to 2024. The solid line (cyan) represents the best-fit growth function with variance (shaded region) estimated as a linear function of length-at-age (σ_1: 0.1 to 7 yrs; σ_2: 7 to 33 yrs).

Appendix 1
SEDAR Data Best Practices Template (Updated version December 2022)

Based on SEDAR. 2015. SEDAR Procedural Workshop 7: Data Best Practices. SEDAR, North Charleston SC. 151 pp. available online at: http://sedarweb.org/pw-07

Field Name	Description	Type	Units	Acceptable Values
SEDAR	Year SEDAR is scheduled to start and assigned SEDAR number. Refer to SEDAR Projects List for Start Year.	Text		yyyySEDARxxx
SEDAR_Date_Submit[3]	Month and Year data submitted to data assessors, this can be added by LHG data compiler (ex: June_2015).	Text		Month_Year
Species	Current scientific name.	Text		
Stock[1]	Stock identification based on stock definition through Stock ID process (ex: Gulf of Mexico, South Atlantic, or Caribbean). See most recent SEDAR Documentation for Terms of Reference.	Text		Gulf of Mexico Gulf of Mexico and South Atlantic South Atlantic Caribbean Atlantic Mixing Zone
Data_Provider[1]	Name (acronym) of agency or university providing the life history dataset to SEDAR. The list is not exclusive/exhaustive. Add acronym as appropriate and define in metadata. This does not include sampling program within data provider (See Sampling_Program descriptor below).	Text		NMFS Panama City–AGR NMFS Panama City–BSD NMFS Beaufort GulfFIN - Gulf States Marine Fisheries Commission, Fisheries Information Network FWRI - Florida Fish and Wildlife Conservation Commission, Florida Wildlife Research Institute USF - University of South Florida USA_DISL - University of South Alabama/Dauphin Island Sea Lab SCDNR - South Carolina Department of Natural Resources NCDMF - North Carolina Division of Marine Fisheries GADNR - Georgia Department of Natural Resources TPWD - Texas Parks and Wildlife Department
Sampling_Program[1]	Sampling Program that collected morphometric data and/or life history sample. Can use acronym as long as more detail is provided in	Text		CRP - Cooperative Research Program EASA - Expanded Annual Stock Assessment Survey, NMFS Pascagoula, MS FIN-OBS - Fishery Information Network, Headboat Observer

Field Name	Description	Type	Units	Acceptable Values
	the metadata tab. Formerly called "Source".			FWRI - Florida Fish and Wildlife Conservation Commission, Florida Wildlife Research Institute FWRI-FIM - Florida Wildlife Research Institute, Fisheries Independent Monitoring FWRI-OBS - Florida Wildlife Research Institute, Observer GHC - IFQ GOP - Galveston Observer Program LABIO - Louisiana Biological Sampling Program MRIP - Marine Recreational Informational program MSLAB - NMFS Pascagoula, MS PCLAB - NMFS Panama City, FL RECFIN - Recreational Fisheries Information Network SBLOP - NOAA Fisheries, Shark Bottom Longline Observer Program SERFS - Southeast Reef Fish Survey SRHS - Southeast Region Headboat Survey TIP - Trip Interview Program TPWD_TSHMP - Texas Parks and Wildlife Department, Texas Sport-Harvest Monitoring Program USGS - U.S. Geological Survey UN - Unknown
Sample_Method_Type[2]	Record how sample was collected by sampler. This will need to be described by individual data sources.	Text		As Available At Sea Unsorted Landed, Sorted Landed, Unsorted Quota Sampling Random Intercept Targeted Biological Voluntary Voluntary/seizure SERFS Sampling SRHS Sample Method MS Lab Reef Fish Sample Method (Blank values are acceptable, if Random or Bias_Type are recorded)
Random[2]	Record if sample was randomly collected based on collection method. This is being pulled from TIPS as IS_Random, or contributor's data submission.	Text		Y - Yes N - No (Blank values are acceptable, if Sample_Method_Type or Bias_Type are recorded)
Bias_Type[2]	Record if the sample was collected using a bias method. This will need	Text		Unspecified Bias No Bias Known

Field Name	Description	Type	Units	Acceptable Values
	to be described by individual data sources.			Effort Bias No Information Size Bias Size and Effort Bias Targeting Sex Bias Donated (e.g., Carcass) Other (please describe in metadata) (Blank values are acceptable, if Sample_Method_Type or Random are recorded)
Fishery[1]	Broad designation as recreational, commercial or fishery independent based on Fishing_Mode.	Text		REC - recreational COM - commercial FI - fishery independent UN - Unknown
Fishing_Mode[1]	Type of fishing activity listed for fishery-dependent and fishery-independent samples identified to the trip level. For Special permitted trips, be sure to include a description or working paper to SEDAR or Life History group describing how the data were collected and why they should or should not be used to characterize the landings (randomly collected, included in other program such as TIP or SRHS).	Text		CM - Commercial CB - Charter Boat CB_EFP - Charter with Exempted Fishing Permit CBHB - Combined Charter Boat and Headboat HB - Headboat HB_EFP - Headboat with Exempted Fishing Permit PR - Private Vessel PR_EFP - Private Vessel with Exempted Fishing Permit PRSH - Combined Private Vessel and Shore Mode REC - Recreational – specific vessel type not reported SH - Shore mode SS - Scientific Survey (e.g., SERFS, PascLL, Special project) TRN - Tournament UN - Unknown
Sampling_Unit_ID[1]	Interview or collection number - identifies a unique trip/collection from within a sampling program.	Text		
Specimen_ID[1]	Unique identifier, assigned by the sampling program for an individual fish within sampling unit ID.	Text		
DP_Unique_Identifier	Unique number or identifier assigned by the Data Provider (e.g., auxiliary number or barcode).	Text (no spaces)		
Month[1]	Month sample collected.	Integer		If unknown fill with 99
Day[1]	Day sample collected.	Integer		If unknown fill with 99
Year[1]	Year sample collected.	Integer		If unknown fill with 9999
Catch_Time	Time of day fish was caught (include time zone in metadata).	Numeric		Military time 0000 - 2400

Field Name	Description	Type	Units	Acceptable Values
State_Landed[1]	Postal state abbreviations from USPS. If a sample was collected through a Scientific survey (Fishery-independent program, and the fish is not landed), then it'll be labeled as NL (Not landed as part of fishery-dependent landings).	Text		Postal code (e.g., FL) NL - Not Landed UN – Unknown Other code for combined states could be FA = west Florida/Alabama; GF = Georgia/Florida, etc.
County_Landed	Fishery-dependent data (COM, REC) - county landed. Fishery-independent data, this may reflect a specific sampling site. If available, otherwise leave blank.	Text		Capitalize, spell out, but can use ST for Saint; no punctuation or underscores (e.g., ST LUCIE, ST JOHNS)
Headboat_Area	Headboat Area assigned by the SRHS.	Integer		1-29
NMFS_Statistical_Grid	Standard statistical grid including sub-areas (decimals).	Numeric		
Latitude	Latitude of where fish was caught.	Numeric	Decimal Degrees	
Longitude	Longitude of where fish was caught.	Numeric	Decimal Degrees	Include the negative sign
Gear_Code	Specific Gear Code (alpha or numeric) used by sampling program – provide a complete list, specific to sampling program.	Text		
Gear_Name	Text description of the Gear Code – provide a complete description.	Text		
Gear_Group_Code[1]	Collapsed grouping of the Gear Code using acronyms. If additional values, please provide value and description in order to cross reference to NMFS codes if necessary.	Text		HL - Hook and-Line (Handline, vertical hook and line gear with limited number of hooks, but not longline) LL - Long-Line SP - Spear TRP - Trap TRW - Trawl GN - Gillnet CN - Castnet SN - Seine Net TN - Trammel Net VLL - Vertical Longline UN - Unassigned, unknown, or combined gear
Min_Depth	Minimum depth of fishing. If only one depth provided, put in this column.	Numeric	meters	
Max_Depth	Maximum depth of fishing.	Numeric	meters	
Jurisdictional_Waters	Refers to water body jurisdiction where fish was caught.	Text		Federal State

Field Name	Description	Type	Units	Acceptable Values
Distance_From_Shore	Record the distance from shore where the fish was caught. Leave blank if unknown.	Numeric	Nautical Miles	
Original_Length_Unit	Length unit used in measurement (cm, mm, inches) recorded by the source.	Text		mm cm Inches
Observed_Maximum_TL_mm	Measured maximum total length (i.e. tail pinched).	Integer	mm	
Observed_Natural_TL_mm	Measured natural total length (tail not pinched).	Integer	mm	
Observed_FL_mm	Measured fork length.	Integer	mm	
Observed_SL_mm	Measured standard length.	Integer	mm	
Predicted_Maximum_TL_mm[3]	Use morphometric conversions to calculate- Will be calculated by Life History data compiler.	Integer	mm	
Predicted_Natural_TL_mm[3]	Use morphometric conversions to calculate- Will be calculated by Life History data compiler.	Integer	mm	
Predicted_FL_mm[3]	Use morphometric conversions to calculate- Will be calculated by Life History data compiler.	Integer	mm	
Predicted_SL_mm[3]	Use morphometric conversions to calculate- Will be calculated by Life History data compiler.	Integer	mm	
Final Length_mm[3]	This is the designated length for specific SEDAR. It will vary by species and assessment. A combination of observed and predicted lengths. Will be calculated by Life History data compiler.	Integer	mm	
Final_Length_Type[3]	Is it FL or Natural TL or Maximum TL? Will be recorded by Life History data compiler.	Text		Max_TL Nat_TL FL
Whole_Weight	Measured whole weight.	Numeric	g	
Gutted_Weight	Measured gutted weight.	Numeric	g	
Original_Weight_Unit	Weight unit used in measurement (grams, kilograms, ounces, pounds) recorded by the source.	Text		g kg oz lbs
Fresh_Gonad_Weight[6]	Measured gonad weight from fresh gonads only.	Numeric	g	
Condition_Type	Description of weight recorded (head on; head off, etc.).	Text		Gutted-head on Gutted-head off Racks

Field Name	Description	Type	Units	Acceptable Values
				Whole (round)
Predicted_Whole_Weight[3]	Use morphometric conversions to calculate- Will be calculated by Life History data compiler (start with WW = GW, then WW= FL then WW = maxTL etc.).	Numeric	g	
Final_Whole_Weight[3]	Compilation of measured and predicted.	Numeric	g	
Duplicate_Length	Refers to whether the length is recorded in another data set (Eg., TIP, SRH, SERFS, etc.).	Text		Y - Yes N - No
Annuli_Count	Reader(s) consensus of annuli count.	Integer		
Edge_Type	Reader(s) consensus of edge type, edge type may vary by ageing facility. If other edge types are used, please provide and define.	Text		Codes Description (Gulf States, Atlantic States) 1 opaque zone on margin 2 translucent zone <1/3 complete 3 translucent zone 1/3 to 2/3 complete 4 translucent zone >2/3 to fully complete 9 translucent zone on edge for species with difficult to differentiate 2-4 edge types (e.g., tilefish, gray triggerfish, snowy grouper, etc.) Codes Description (Panama City Lab specific) 2_PC opaque zone complete 4_PC translucent zone forming to < 1/3 complete 6_PC translucent zone 1/3 to fully complete 9_PC translucent zone on edge for species with difficult to differentiate (e.g., tilefish, gray triggerfish, snowy grouper, yellowedge grouper) Codes Description (mackerels only) N None – opaque zone on margin S Small – translucent zone < 1/3 complete M Medium – translucent zone 1/3–2/3 complete L Large – translucent zone 2/3 to fully complete
Calendar_Age	Age assigned to an individual fish to place that fish in a calendar year. Can be considered Cohort age. Allows us to account for time of capture and when it would lay down an annulus. Since it is subjective, it needs to be analyzed by individual reader or	Integer		

Field Name	Description	Type	Units	Acceptable Values
	data provider if consensus age is submitted. To be filled out by data contributors unless it's a species that uses annuli count, then leave blank.			
Final_Age[3]	Age to be used in age compositions during current assessment. Species-specific, could be annuli count or calendar age. To be filled out by data compilers.	Integer		
Fractional_Age[3]	Fractional age assigned to an individual fish based on peak spawning date/month. This will be species- specific. To be filled out by data compilers.	Numeric		Two decimal places
Sub_Sampled	Whether or not an individual fish was subsampled from a larger set of samples. If subsampled, please provide methodology in metadata (e.g. simple random, stratified random, etc.).	Text		Y - Yes N - No
Gonad_Observed[1,4]	Observed in the field (macro assessment, gonad weight).	Text		Y - Yes N - No
Histo_Sample[1,5,6]	Tissue - histologically processed.	Text		Y - Yes N - No
Macro_Sex[4]	Sex identified by field sampler based on macroscopic appearance of gonad.	Text		F - Female M - Male T - Transitional U - Unknown sex D - Did not attempt
Secondary_Sex	Secondary sex based on characteristics expressed in fish size, shape or color.	Text		F - Female M - Male N - None D - Did not attempt
Secondary_Sex_Attribute	A description of the secondary sex attribute (e.g. "copperbelly" in gag, "adipose fin" in tilefish).	Text		Spelled out and lowercase
Macro_Repro_Phase[4]	Maturity based on macroscopic evaluation of reproductive tissue.	Text		IM - Immature MU - Mature, not developed (early developing, spent/regressing, resting/ regenerating) YO - Yolked Oocytes (developing) AS - Active Spawner (hydrated oocytes; milt) DN - Did Not attempt
Histo_Sex[5]	Sex assigned after histological reading of gonad tissue.	Text		F - Female M - Male

Field Name	Description	Type	Units	Acceptable Values
				T - Transitional S - Simultaneous hermaphrodite U - Unknown/lost N - Not gonad tissue
Final_Sex[3]	Compilation of macro and histological sex to be used in sex composition of stock during current assessment. Histological sex will override macro sex if both present. To be filled out by data compilers.			F - Female M - Male T - Transitional S - Simultaneous hermaphrodite U - Unknown
Histo_Historic_Data[5]	Any histological data not recorded following Brown-Peterson et al. (2011) or Lowerre-Barbieri et al. (2023).	Text		Y - Yes N - No
Histo_Repro_Phase[5]	Standardized terminology that includes both males and females. Early Developing phase is equivalent to Early Developing subphase in Brown-Peterson et al. (2011); see also Lowerre-Barbieri et al. (2023); SG+SC1 only in males and PG+CA only in females. Reference documents: (Lowerre-Barbieri et al. (2023) Table 1; Brown-Peterson et al. (2011) Tables 2 and 3; Lowerre-Barbieri et al. (2009) Table 1).	Text		IM - Immature ED - Early Developing LD - Late Developing SP - Spawning RG - Regressing RN - Regenerating TR - Transitional <u>If historic data:</u> DV - Developing <u>If slide quality is compromised</u> MA - Mature, phase unknown UN - Unknown
Histo_Repro_Subphase[5]	Further detailed information of Histo_Repro_Phase. For description of male GE subphases, see Brown-Peterson et al. (2011) and Lowerre-Barbieri et al. (2023). Other subphases from Table 1 in Lowerre-Barbieri et al. (2023).	Text		NON - None <u>Female:</u> ISP - Imminent Spawning. Subphase of female SP ASP - Active Spawning. Subphase of female SP ; ±2 hours of a spawning event RSP - Recent Spawning. Subphase of female SP <u>Male:</u> EGE - Early spawning season. Subphase of male SP LGE - Late spawning season. Subphase of male SP UN – Unknown/Did Not Attempt <u>Hermaphrodites</u>: ETR - Early Transitional

Field Name	Description	Type	Units	Acceptable Values
				LTR - Late Transitional JTR - Juvenile Transitional
Histo_Most_Advanced_Gamete_Stage[5,6]	Males and females. Stage must occur in ≥ 5% of the tissue section to be considered "most advanced". Scan of the entire slide: 4x on female tissue and 10x on male tissue.	Text		UN - Unknown/Did not attempt Female: PG - Primary Growth oocyte CA - Cortical Alveolar V1 - Primary Vitellogenesis V2 - Secondary Vitellogenesis V3 - Tertiary Vitellogenesis LC - Lipid Coalescence YC - Yolk Coalescence GM - Germinal vesicle Migration GB - Germinal vesicle Breakdown HO - Hydration/Ovulation If historic female data: VT - Vitellogenesis OM - Oocyte Maturation Male: SG - Spermatagonium (substage unknown) G1 - Primary Spermatogonium G2 - Secondary Spermatogonium SC - Spermatocyte (substage unknown) C1 - Primary Spermatocyte C2 - Secondary Spermatocyte ST - Spermatid SZ - Spermatozoa
Histo_POF[5,6]	Relative age of post-spawning indicator. POF = postovulatory follicle.	Text		N - None C - Newly Collapsed R - Recent B - Both Newly Collapsed and Recent POFs present If historic data: P - Present, unknown age U - Unknown
BF_Est[6]	Batch fecundity estimate.	Numeric		Actual number
BF_Pres[6]	How were gonads for fecundity preserved?	Text		FM - Formalin GL - Gilson's FR - Frozen NA - No tissue preserved
Histo_Melanomacrophages	One or more melanomacrophage centers observed in the gonad.	Text		Y - Yes N - No U - Unknown/did not assess

Field Name	Description	Type	Units	Acceptable Values
Macro_Gonad_Parasites	Macroscopic evidence of parasitic infection anywhere in gonad.	Text		Y - Yes N - No U - Unknown/did not assess
Histo_Gonad_Parasites	Histological evidence of parasitic infection anywhere in gonad.	Text		Y - Yes N - No U - Unknown/did not assess
Histo_Indicator_1	Other structures found within the histological section that support Histo_Repro_Phase classifications, especially in the case of immature vs regenerating specimens. Order of three Histological Indicator fields does not indicate priority.	Text		U - Unknown/Did not attempt Female: AB - Alpha/Beta atresia of yolked oocytes GD - Gamma/Delta atresia BV - Blood Vessels evident throughout MB - Muscle Bundle TN - Thin ovary wall TK - Thick ovary wall Male: RZ - Residual Spermatozoa SP - Spermatogonia Proliferation Hermaphrodite: MT - Male Tissue present in functional female FT - Female Tissue present in functional male TR - Transitional (degeneration of one sexually mature tissue, proliferation of tissue of other sex) FM - can function (reproduce) as female and male at the same time, or within short span of time
Histo_Indicator_2	Other structures found within the histological section that support Histo_Repro_Phase classifications, especially in the case of immature vs regenerating specimens. Order of three Histological Indicator fields does not indicate priority.	Text		UN - Unknown/Did not attempt Female: AB - Alpha/Beta atresia of yolked oocytes GD - Gamma/Delta atresia BV - Blood Vessels evident throughout MB - Muscle Bundle TN - Thin ovary wall TK - Thick ovary wall Male: RZ - Residual Spermatozoa SP - Spermatogonia Proliferation Hermaphrodite: MT - Male Tissue present in functional female FT - Female Tissue present in functional male

Field Name	Description	Type	Units	Acceptable Values
				TR - Transitional (degeneration of one sexually mature tissue, proliferation of tissue of other sex) FM - can function (reproduce) as female and male at the same time, or within short span of time
Histo_Indicator_3	Other structures found within the histological section that support Histo_Repro_Phase classifications, especially in the case of immature vs regenerating specimens. Order of three Histological Indicator fields does not indicate priority.	Text		UN - Unknown/Did not attempt <u>Female:</u> AB - Alpha/Beta atresia of yolked oocytes GD - Gamma/Delta atresia BV - Blood Vessels evident throughout MB - Muscle Bundle TN - Thin ovary wall TK - Thick ovary wall <u>Male:</u> RZ - Residual Spermatozoa SP - Spermatogonia Proliferation <u>Hermaphrodite:</u> MT - Male Tissue present in functional female FT - Female Tissue present in functional male TR - Transitional (degeneration of one sexually mature tissue, proliferation of tissue of other sex) FM - can function (reproduce) as female and male at the same time, or within short span of time