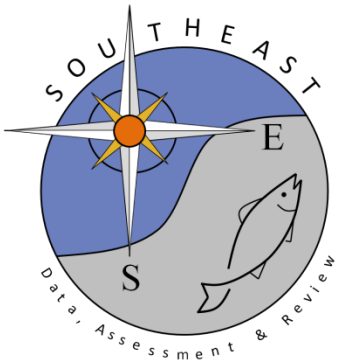
Age frequency distributions, age length keys, length at ages, and sex ratios for king mackerels in the Gulf of Mexico and South Atlantic from 1986-2013

Ching-Ping Chih

SEDAR38-AW-05

20 March 2014



Please cite this document as:

Chih, C. 2014. Age frequency distributions, age length keys, length at ages, and sex ratios for king mackerels in the Gulf of Mexico and South Atlantic from 1986-2013SEDAR38-AW-05. SEDAR, North Charleston, SC. 44 pp.

Age frequency distributions, age length keys, length at ages, and sex ratios for king mackerels in the Gulf of Mexico and South Atlantic from 1986-2013

Ching-Ping Chih

Introduction

This report documents changes in the age frequency distributions (AFDs) of king mackerels collected from the Gulf of Mexico (GOM) and the South Atlantic (ATL) from 1978 to 2013. Methods for estimating AFDs for king mackerels in SEDAR 38 differ from those used in SEDAR 16 in several ways : (1) the stock definitions for GOM and ATL have been significantly changed, (2) fishing areas, instead of landing areas, have been used when available to define stocks for the age and length samples, (3) AFDs for two new strata (gill net and tournament samples) have been estimated, and (4) for years before 1986, combined age length keys (ALKs) from all previous years were used to estimate AFDs for individual years. In this document, AFDs for the winter mixing zone (WMZ) were not estimated due to inadequate age and length sample sizes for the WMZ. In addition, length at age and sex ratios were estimated to examine the potential influence of the ALK-sampling method on these parameters.

Materials and Methods

Age frequency distributions were estimated from length frequency distributions and age length keys. Sources of length samples and definition of stocks have been described elsewhere (Chih, 2014). Age samples were from the Panama City laboratory and the Gulf FIN database. The definition of stocks, region and fishing years for the age samples were the same as those for the length samples. Only age samples collected from commercial and recreational fisheries were used for the estimation of age length keys.

Age samples were subsamples of length samples and may represent less than 10% of length samples in many strata/fishing years. Because of the ALK sampling method (non-random sampling by size) used before 2004 (Saari, 2013), age samples in many strata/fishing years may not represent random samples from length samples. As a result, age samples cannot be used directly to estimate

AFDs. Also, other parameters, such as lengths at age, growth curves and sex ratios may also be influenced by non-random sampling.

In this document, ALKs were estimated for the GOM and the ATL stocks. As was the case for length samples, ALKs for the WMZ were not estimated due to small sample sizes (see Chih, 2014 for details). Divisions of ALKs into different modes were not possible due to small sample sizes. For years before 1986, combined ALKs from 1986 to 2012 were used for estimating AFDs from LFDs. This method is different from the stochastic method, which assumes constant lengths at age, used in SEDAR 16 (Ortiz, 2008) . The two methods were compared in a previous study (Chih, 2008).

In addition to AFDs and ALKs, lengths at age were analyzed for different stocks, modes and sexes. Sex ratios estimated from length and age samples were compared to examine the potential influence of non-random sampling on these ratios.

Results and Discussion

ALK

The differences in ALKs between the GOM and ATL stocks and among different fishing years were illustrated by comparing the age length keys at the 80 cm length interval, where the sample sizes were usually the largest (Fig 1 (a)-(d)). There were noticeable differences in ALKs between the GOM and the ATL stocks and among different fishing years. These differences in ALKs reflected differences in year class strength, growth and age selectivity among different stocks and fishing years.

AFD

There was considerable variation in AFDs between the GOM and the ATL stocks, among different strata, and among different fishing years (Figs 2-7). The differences in AFDs reflected the differences in LFDs (Chih, 2014) and ALKs among stocks, strata and fishing years. As expected, there were higher proportions of older fish for AFDs estimated from tournament samples. Different age/size selectivity, year class strengths, fishing practices and other environmental factors

may have contributed to the differences seen in the AFDs among different stocks, strata and fishing years.

Length at age

Lengths at age estimated from tournament samples, especially those samples collected from the GOM stock, were noticeably larger than those estimated from other fisheries (Fig 9 (a)(b)). This large LAA is likely due to sampling bias toward large fish for tournament fishing. The large LAAs for tournament samples also coincided with a large dispersion in length frequency distributions for tournament samples (Chih, 2014). Biased LAAs for tournament samples can influence the precision of growth curves estimated from these samples (Chih, 2009). Since tournament samples represent a significant portion of age fisheries samples from both the GOM (14.7%) and the ATL stocks (34.4%), it may be necessary to remove those samples for growth curve estimations. Note that inclusion of tournament samples for the estimation of ALKs does not influence the precision of ALKs since ALKs are estimated by different size categories.

Lengths at age estimated from female samples were noticeably larger than those estimated from male samples for both the GOM and the ATL stocks (Figs 10-11). Since the ALK sampling method oversamples larger fish, this sampling method may influence the LAAs estimated from females more than those estimated from males. The apparent differences in size and growth between the two sexes have important implications for the estimation of growth curves and length frequency distributions. Because of the effect of non-random sampling on both LAAs and sex ratios, any comparison of growth curves between different strata should take the sampling methods and sex ratios into consideration.

Sex ratios

The total sex ratios (male/female) estimated from commercial length samples were significantly different those estimated from age samples (Table 4 (a)(b)). These differences in total sex ratios between length and age samples were seen in all years and were more noticeable in the ATL stock (Fig 12). These differences can be attributed in part to the ALK sampling method (non-random sampling by size) used to collect otolith samples, which oversampled larger fish that were mostly female. Another reason for the differences in sex ratios may be the

difference in proportions of length and age samples collected for different months. The sex ratios in king mackerel landings varied greatly during the spring run of king mackerels (April-June). There was a noticeable shift of sex ratios in commercial length samples, with a large increase in male king mackerels in the spring (Figs 13, 15). The changes in sex ratios during the spring run were also seen in commercial age samples in the ATL but not in the GOM (Figs 14, 15), possibly due to the small sample sizes and non-random sampling by size, which favors the collection of larger numbers of female fish. Commercial length samples collected during the spring run represented 32.4% of total samples in the ATL and 5% samples in the GOM, while commercial age samples collected during the spring run represented 21.5% of total samples in the ATL and 2.3% samples in the GOM. These differences in the proportions of the spring run samples help explain some of the differences in sex ratios between length and age samples from different stocks.

There were also significant differences in the sex ratios by size between the length and age samples, with the percentage of males being higher in the length samples than in the age samples (Fig 18). These differences may be due to different proportions of spring run samples in the two sample types. Also, the sex ratios by size are larger in the ATL than those in the GOM, reflecting the higher proportion of spring run samples in the ATL. Sex ratios were also different for different fishing modes. In particular, tournament samples had a low male to female ratio, as expected from the bias toward larger fish among tournament samples.

References

Chih, C.P., 2008, On the choice of length-to-age conversion methods, SFD-2008-17

Chih, C.P. 2009, The effects of otolith sampling methods on the precision of growth curves, North American Journal of Fisheries Management, 29: 1519-1528.

Chih, C.P. 2014, Length frequency distributions for king mackerels in the Gulf of Mexico and South Atlantics from 1978-2013. SEDAR 38-DW.

Ortiz, Mauricio, 2008. Review of catch, catch at size, sex ratios and catch at age of king mackerel from the U.S. Gulf of Mexico and South Atlantic fisheries. SEDAR 16-DW-28.

Saari, C. 2013, Sampling history of the king mackerel commercial fisheries in the Southeastern United States by the federal Trip Interview Program. SEDAR 38-DW.

Table 1. Sample sizes for king mackerel otolith samples collected from commercial and recreational fisheries from 1986 to 2013. Stocks: Atlantic (ATL), Gulf of Mexico (GOM), WMZ (winter mixing zone).

Fishing Year	ATL	GOM	WMZ
1986	210	364	
1987	321	252	1
1988	292	526	
1989	885	837	55
1990	950	766	73
1991	973	1344	47
1992	1439	1152	10
1993	873	1246	14
1994	837	963	10
1995	1035	894	75
1996	1936	821	2
1997	726	528	62
1998	848	385	26
1999	1413	331	23
2000	1719	262	65
2001	1510	852	100
2002	1549	1341	123
2003	2498	1289	21
2004	2141	988	75
2005	523	1124	42
2006	773	1008	63
2007	745	1809	68
2008	1500	1731	32
2009	1426	2195	53
2010	1166	1978	165
2011	1199	2450	28
2012	733	1837	3
2013	49		

Table 2. Sample sizes for king mackerel otolith samples collected from different modes of commercial or recreational fisheries from 1986 to 2013. Stocks: Atlantic (ATL), Gulf of Mexico (GOM), WMZ (winter mixing zone); Modes: CM (commercial), CP (charter boat), HB (head boat), PR (private boat), TRN (tournament).

	ATL					GOM					
Fishing Year	**CM**	**CP**	**HB**	**PR**	**TRN**	**CM**	**CP**	**HB**	**PR**	**SH**	**TRN**
1986		79	74	2	55	27	190	42			105
1987		84	81	3	153	10	25	29			188
1988		63	45		184	19	46	169			292
1989	49	93	3	149	591	12	270	136	160		259
1990	68	45		41	796	4	526	94	17		125
1991	230	82	2	52	607	248	530	277	14		275
1992	411	186		6	836	158	378	83			533
1993	351	79		18	425	660	121	125	19		321
1994	467	26		26	318	216	222	70	29		426
1995	739	56		1	239	351	267	1	10		265
1996	1458	4			474	59	514	14	1		233
1997	401			6	319	173	150	6			199
1998	400			2	446	95	145	9	1		135
1999	937	26		12	438	87	146	2	62		34
2000	1182	37			500	141	91	12			18
2001	774	199			537	539	244	8	52		9
2002	842	356	1	13	337	397	519	47	182	4	192
2003	686	786	9	104	913	438	419	8	84	6	334
2004	435	423	131	788	364	316	310	36	179	6	141
2005	149	115	58	16	185	450	349	7	255		63
2006	267	201	43	140	122	385	341	12	241		29
2007	468	22	15	5	235	1266	379	1	163		
2008	1206	13	34	1	246	1133	474	5	119		
2009	1136	14	70	6	200	1341	721	19	98	16	
2010	774	29	103	1	259	1304	519	9	94		52
2011	859	3	30	43	264	1630	563	23	147		87
2012	371				362	1637	129	67	4		

Fig 1 (a). Age length keys for the 80 cm-length interval of age samples collected from commercial and recreational fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1986 and 1990.

(a) GOM

(b) ATL

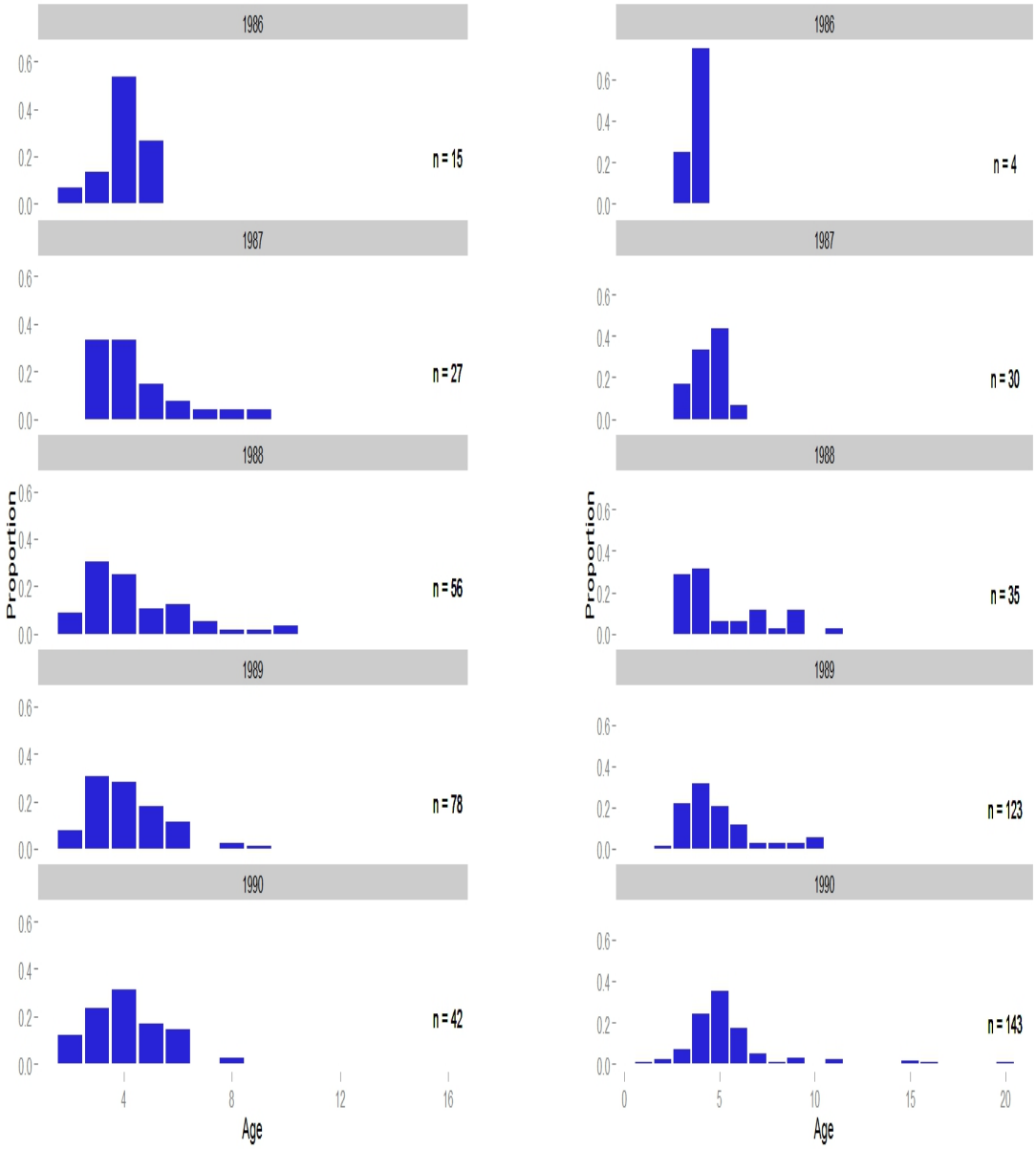
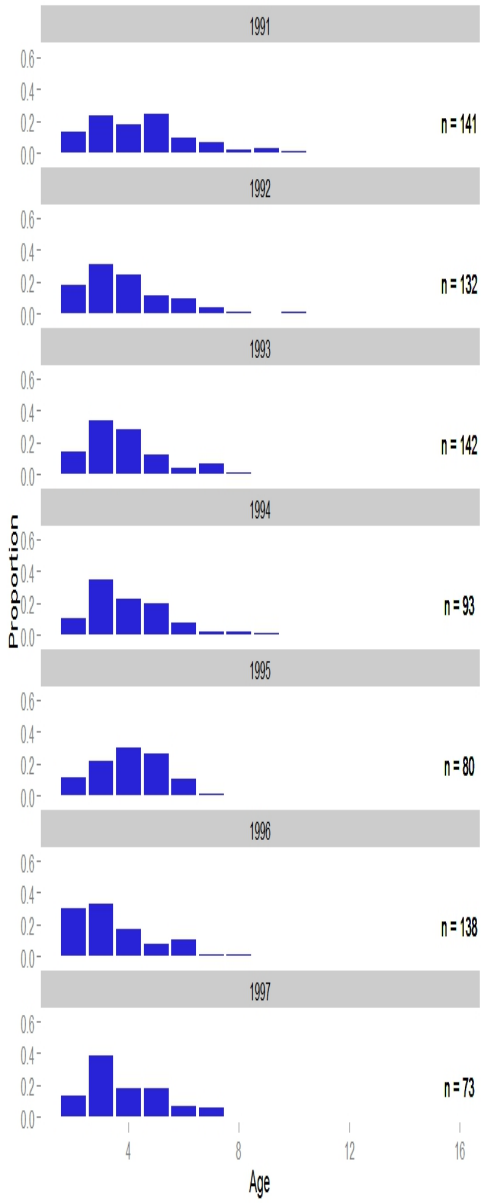


Fig 1 (b). Age length keys for the 80 cm-length interval of age samples collected from commercial and recreational fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1991 and 1997.

(a) GOM



(b) ATL

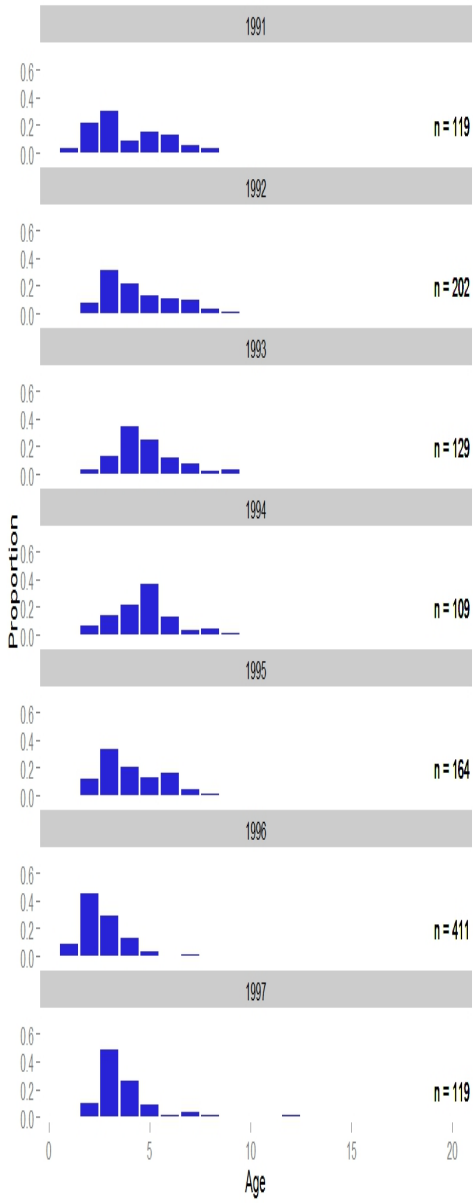
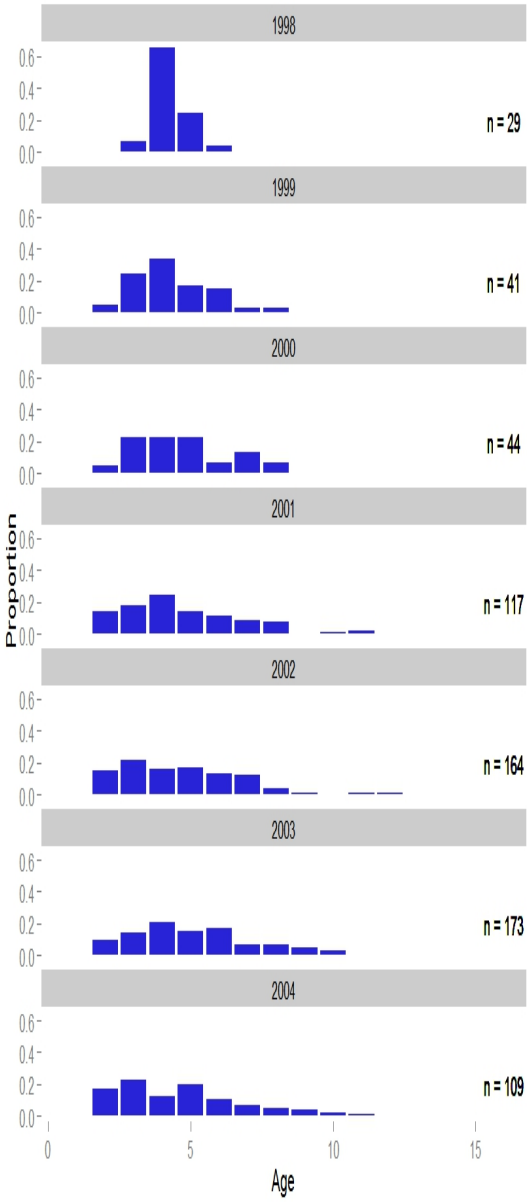


Fig 1 (c). Age length keys for the 80 cm-length interval of age samples collected from commercial and recreational fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1998 and 2004.

(a) GOM



(b) ATL

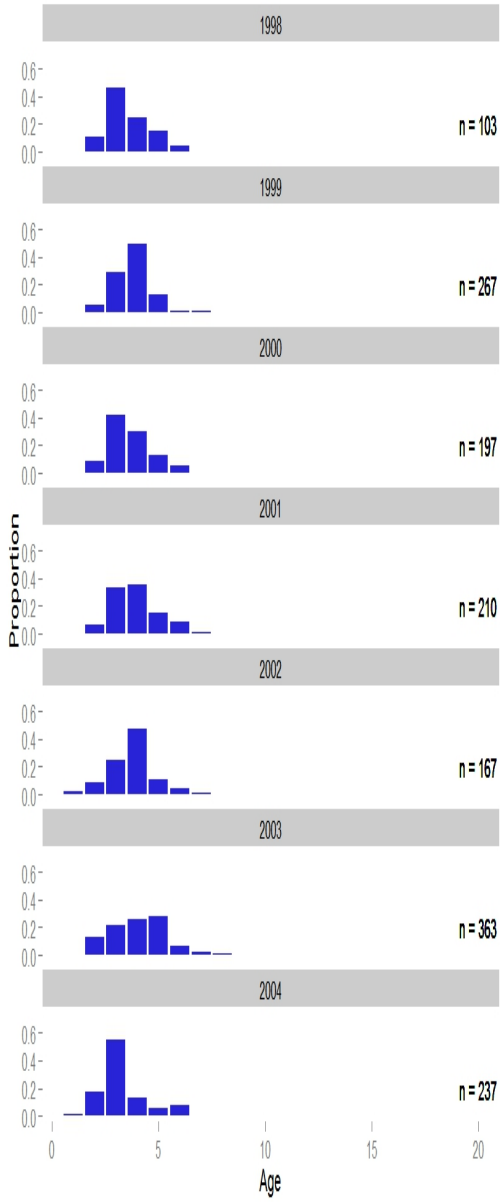
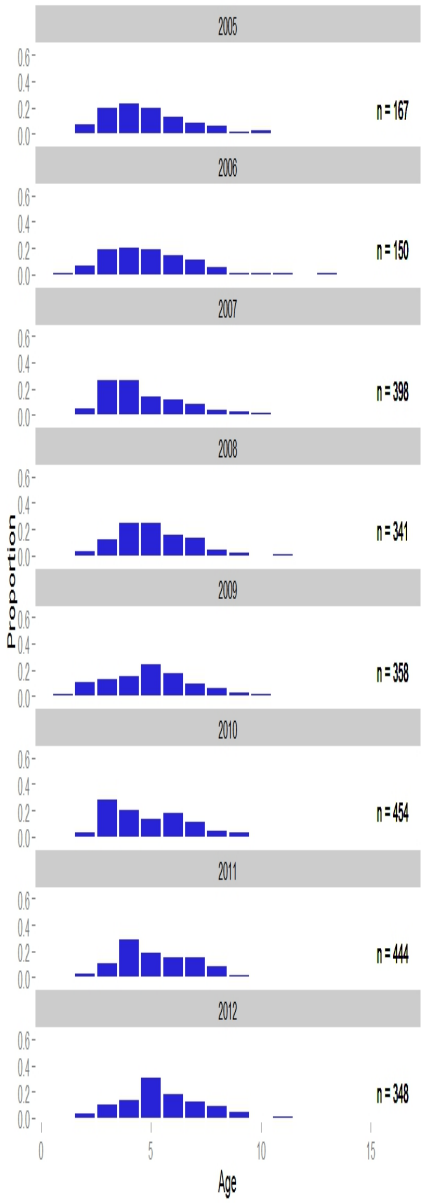


Fig 1 (d). Age length keys for the 80 cm-length interval of age samples collected from commercial and recreational fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 2005 and 2012.

(a) GOM



(b) ATL

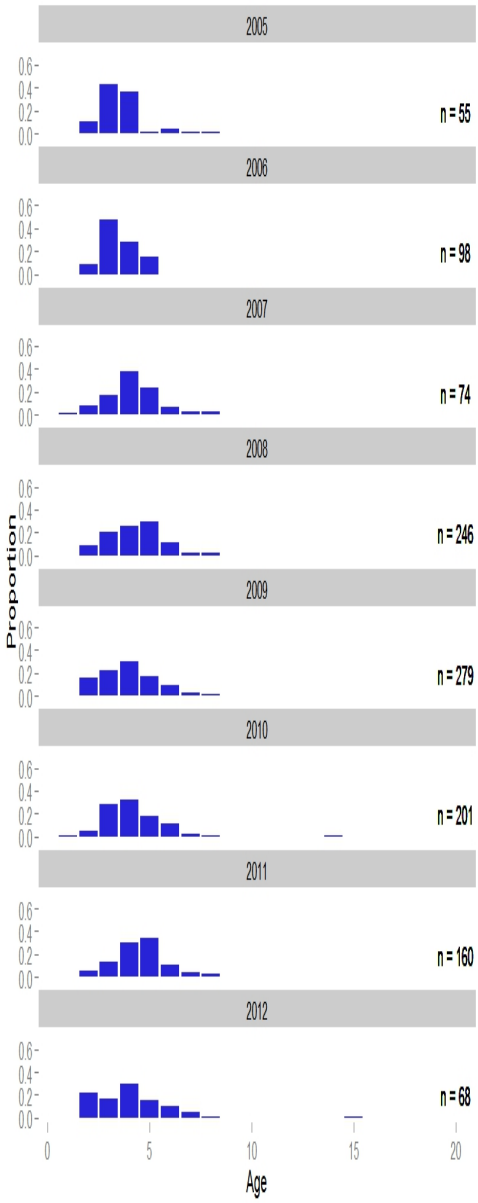


Fig 2 (a). Age frequency distributions for king mackerel age samples collected from commercial handline (HL) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1986 and 1990.

(a) GOM

(b) ATL

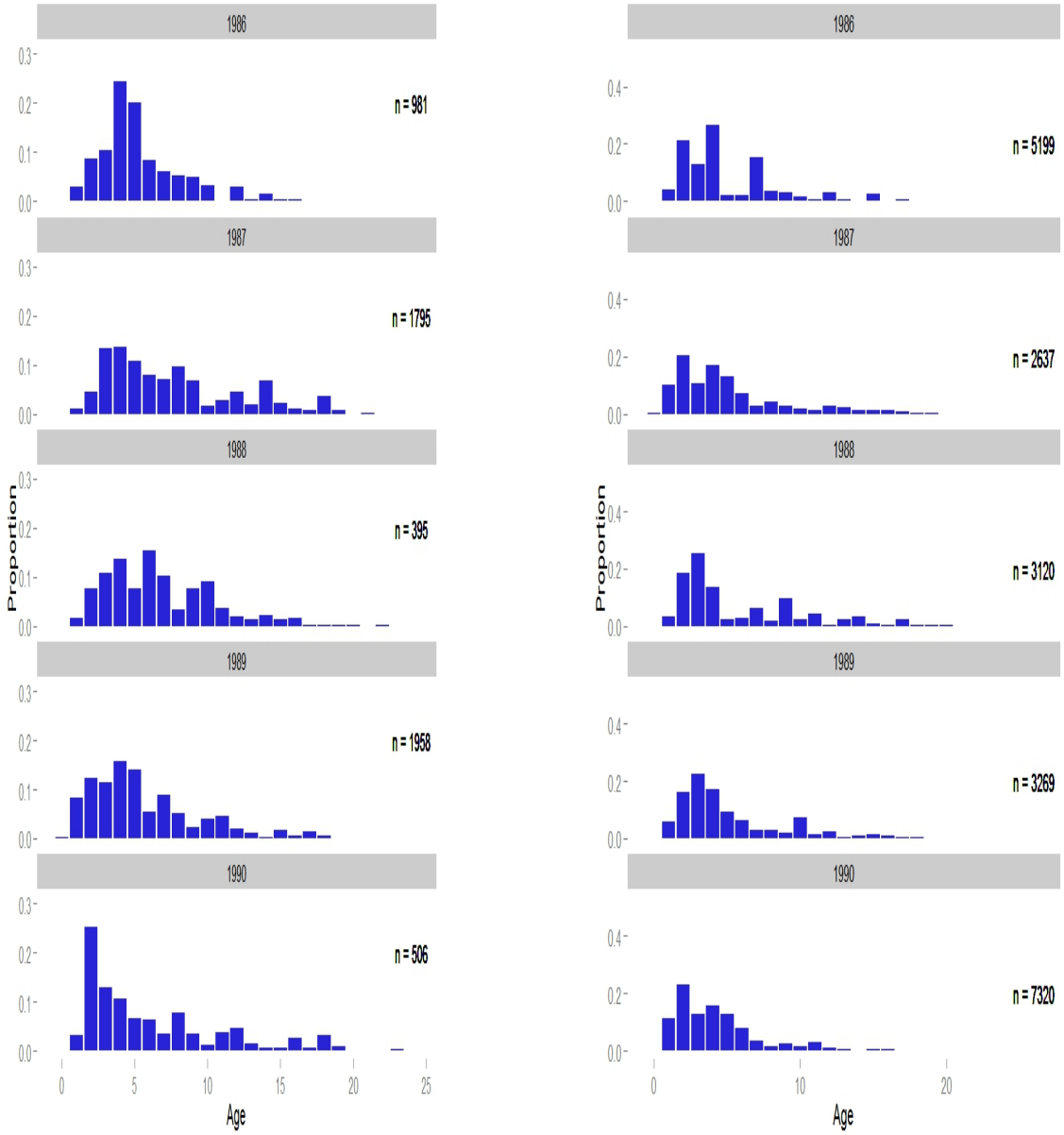
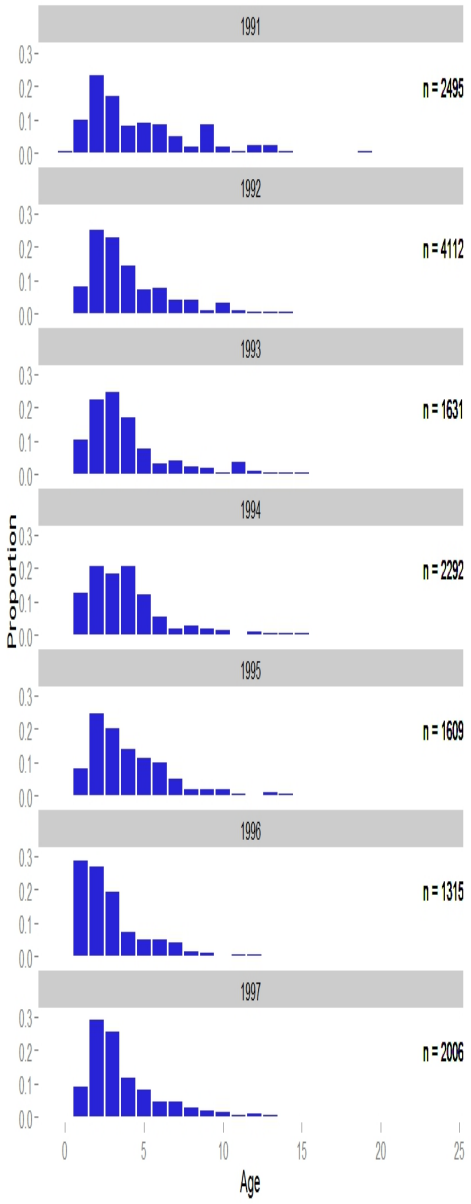


Fig 2 (b). Age frequency distributions for king mackerel age samples collected from commercial handline (HL) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1991 and 1997.

(a) GOM



(b) ATL

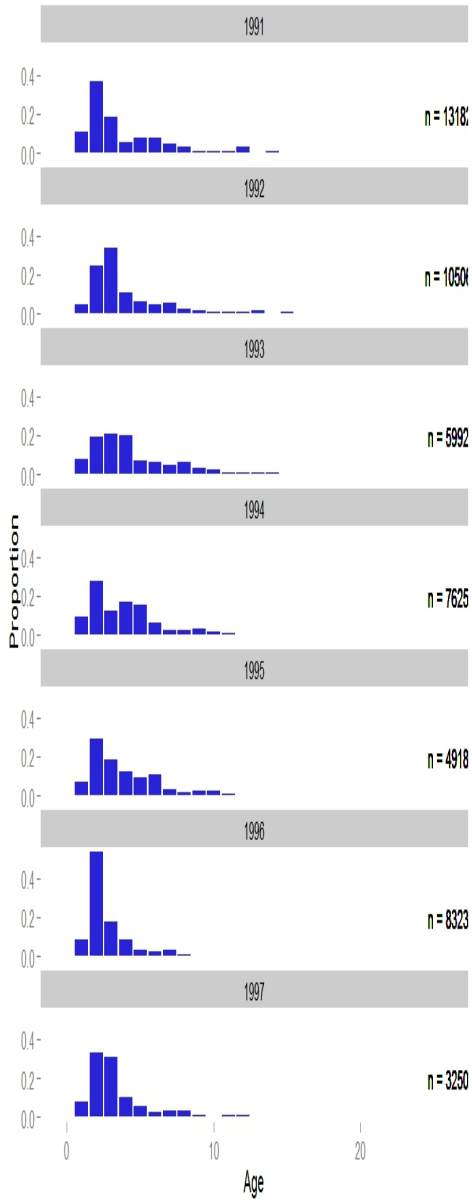
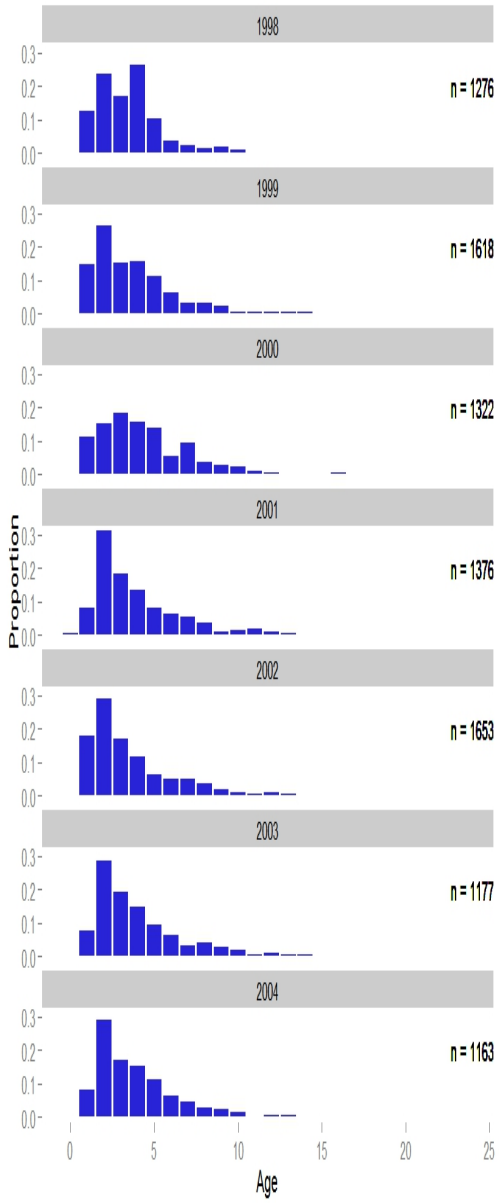


Fig 2 (c). Age frequency distributions for king mackerel age samples collected from commercial handline (HL) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1998 and 2004.

(a) GOM



(b) ATL

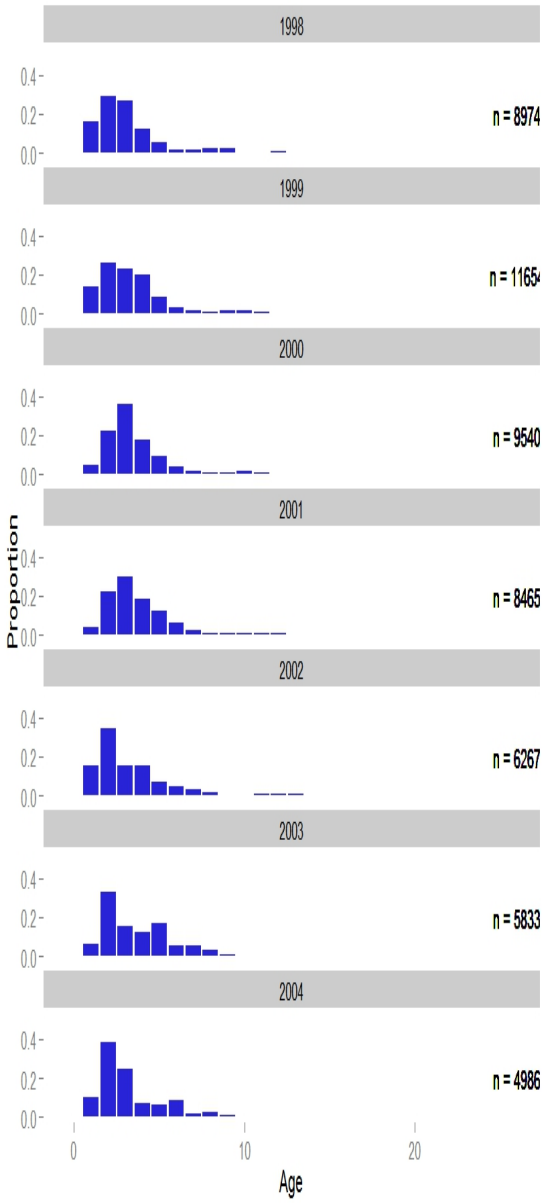
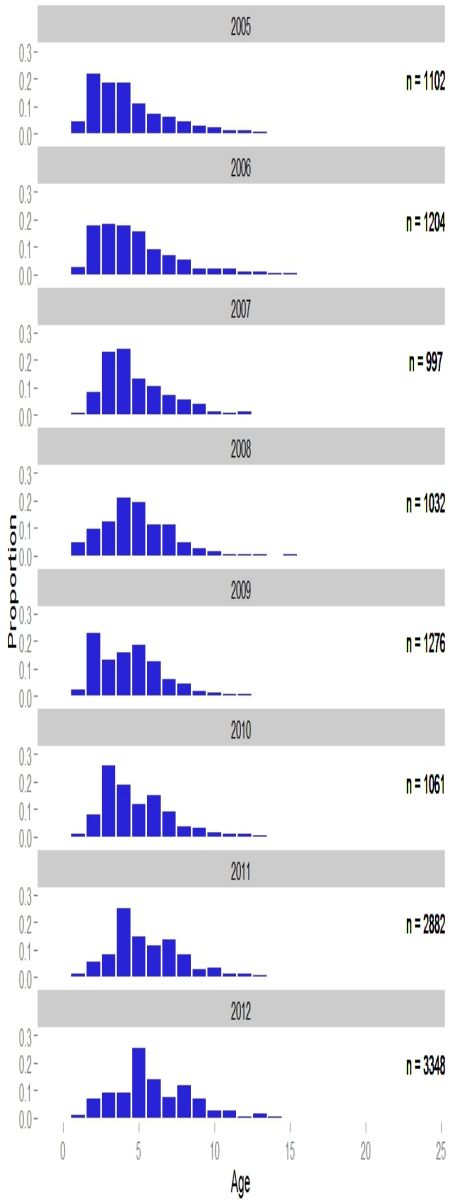


Fig 2 (d). Age frequency distributions for king mackerel age samples collected from commercial handline (HL) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 2005 and 2012.

(a) GOM



(b) ATL

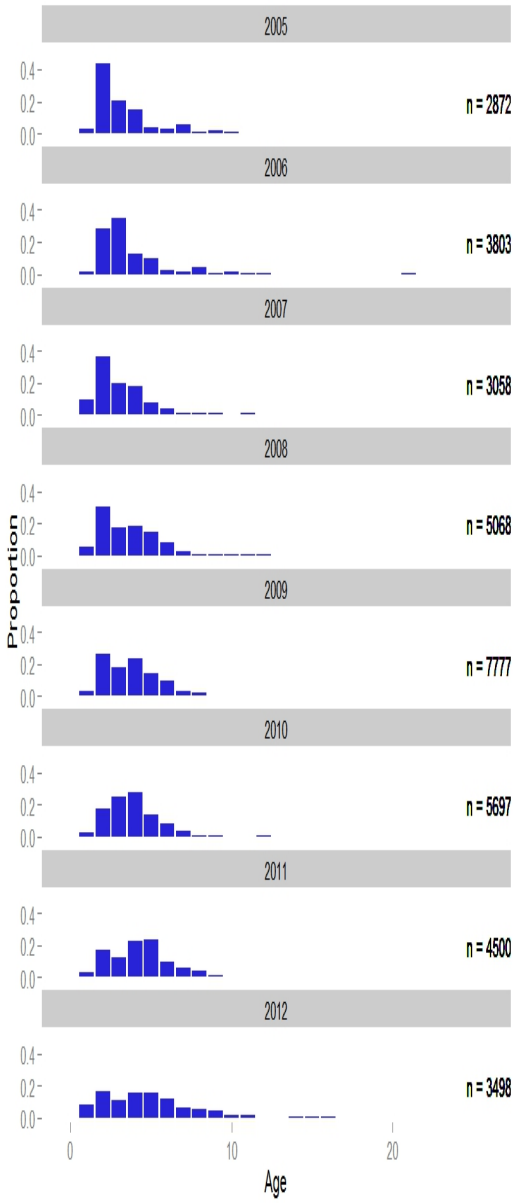
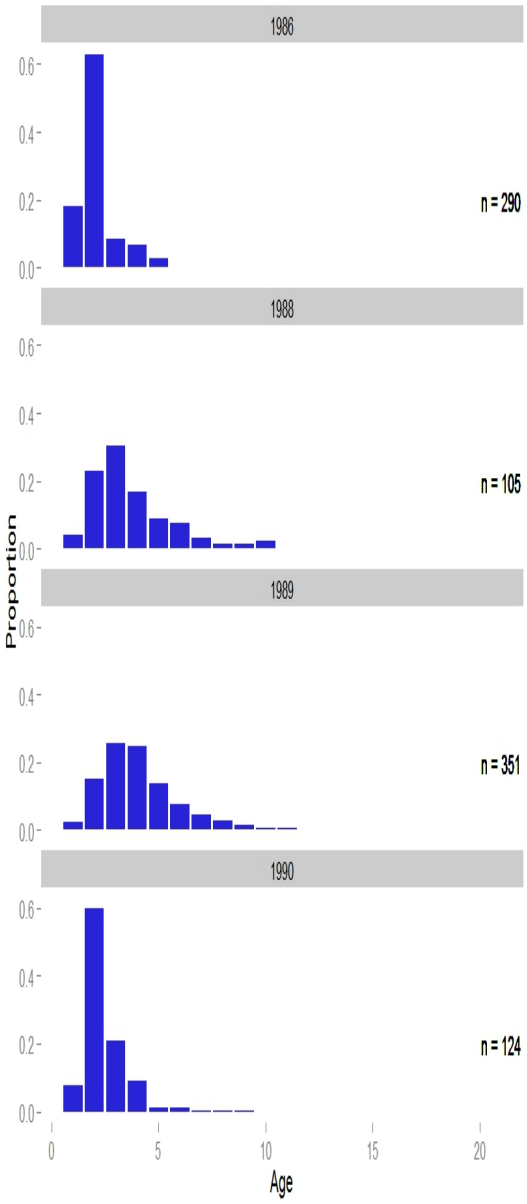


Fig 3 (a). Age frequency distributions for king mackerel age samples collected from commercial gill net (GN) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1986 and 1990.

(a) GOM



(b) ATL

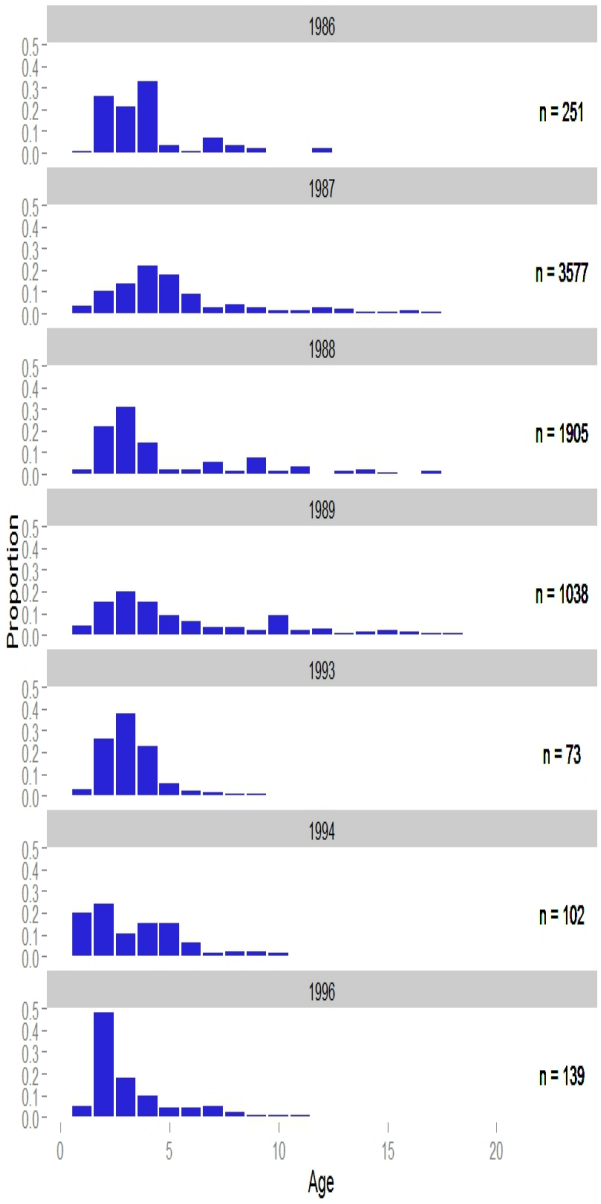


Fig 3 (b). Age frequency distributions for king mackerel age samples collected from commercial gill net (GN) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1991 and 1997.

(a) GOM

(b) ATL

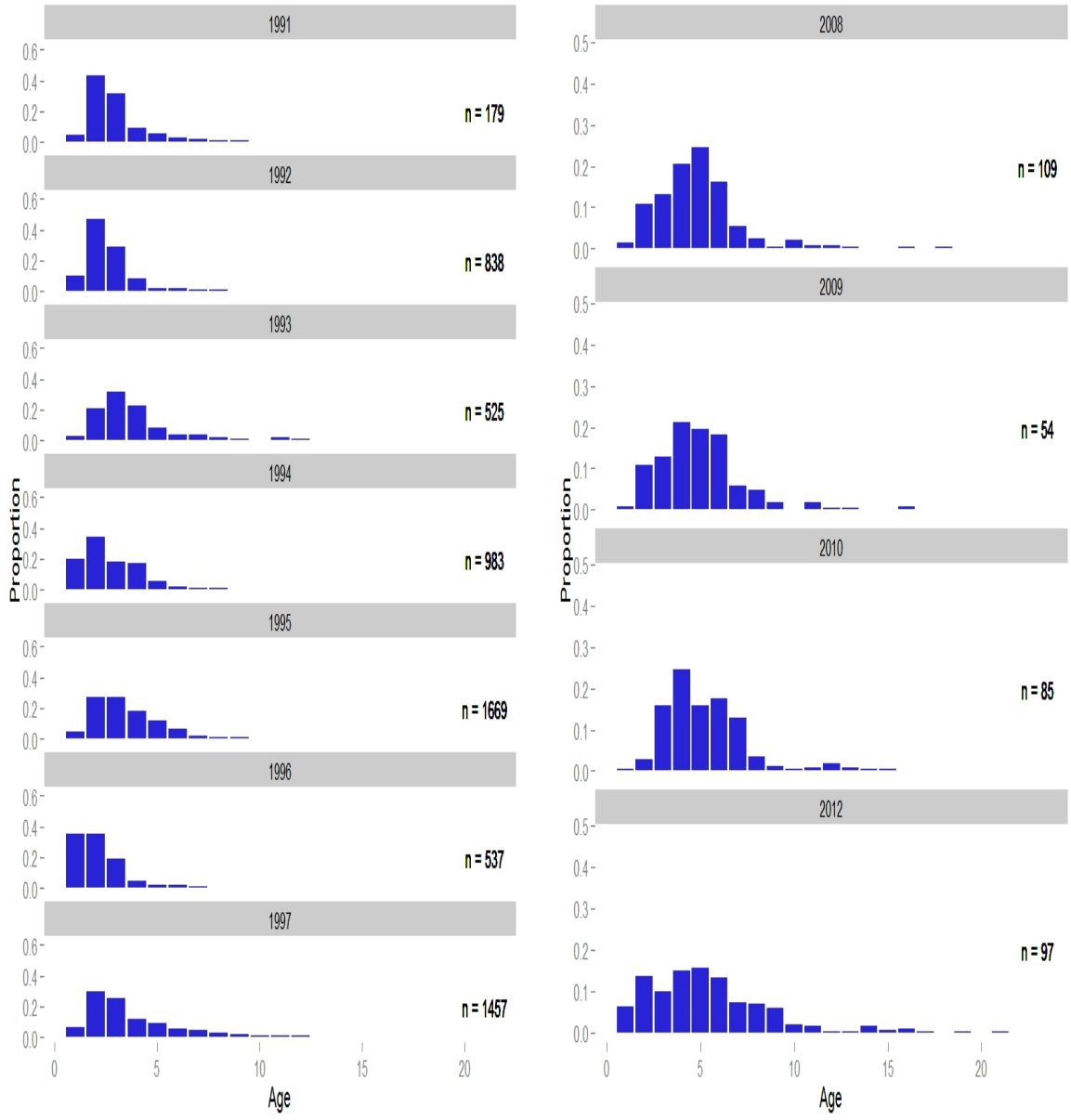
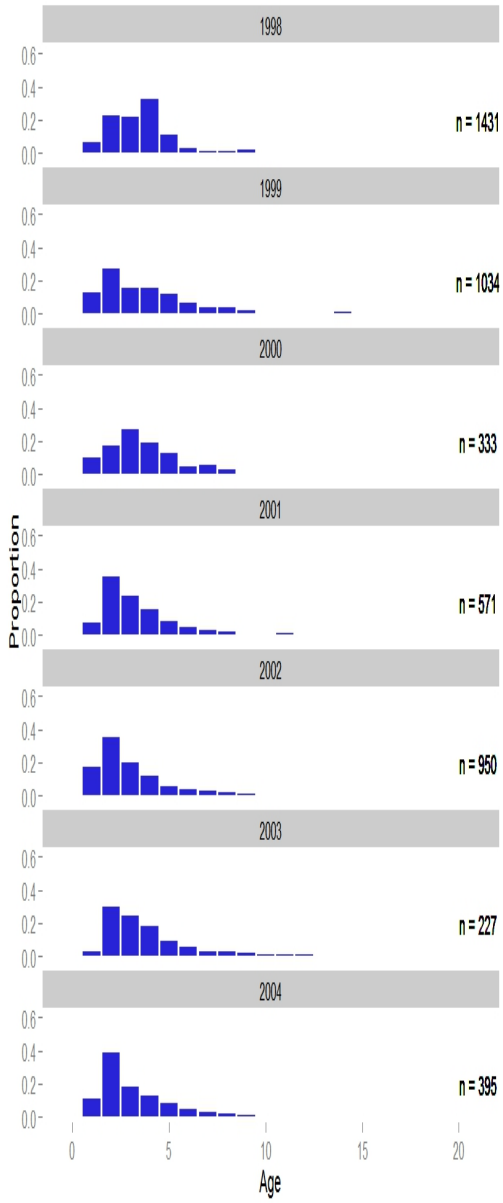


Fig 3 (c). Age frequency distributions for king mackerel age samples collected from commercial gill net (GN) fisheries from the Gulf of Mexico (GOM) between 1998 and 2012.

(a) GOM 1998-2004



(b) GOM 2005-2012

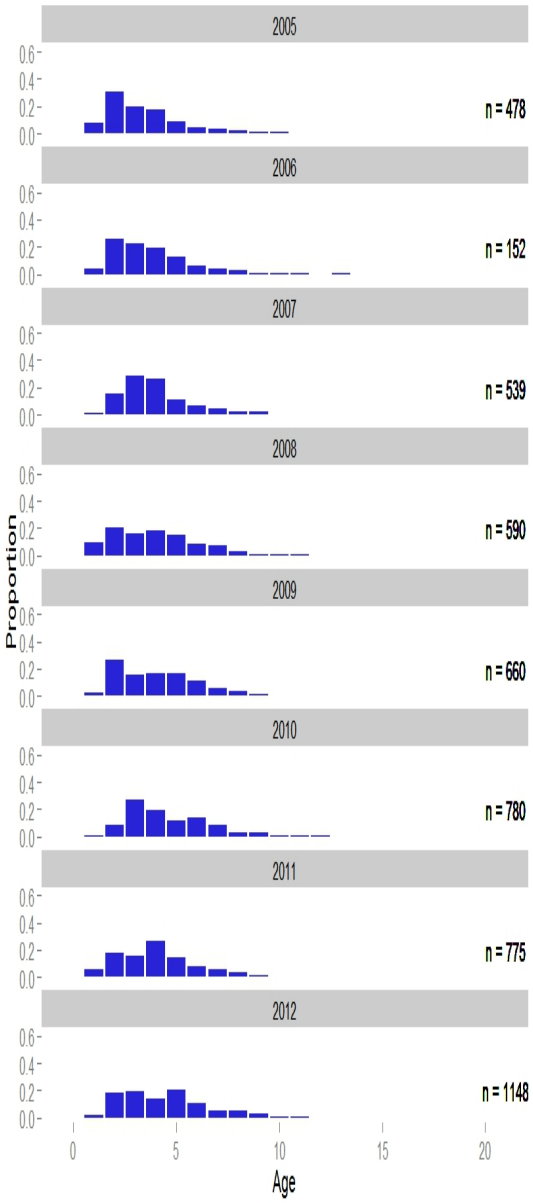
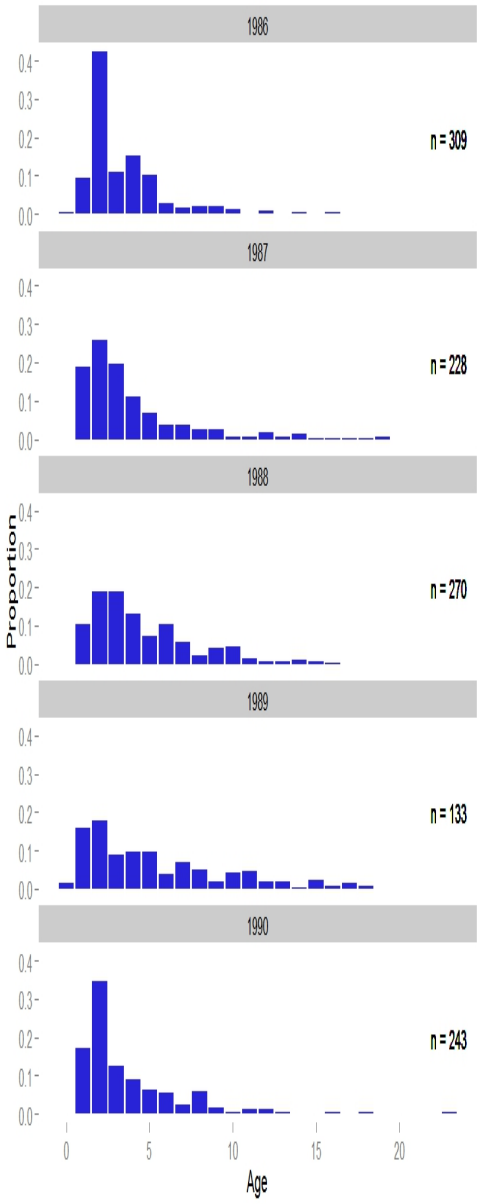


Fig 4 (a). Age frequency distributions for king mackerel age samples collected from charter boat (CP) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1986 and 1990.

(a) GOM



(b) ATL

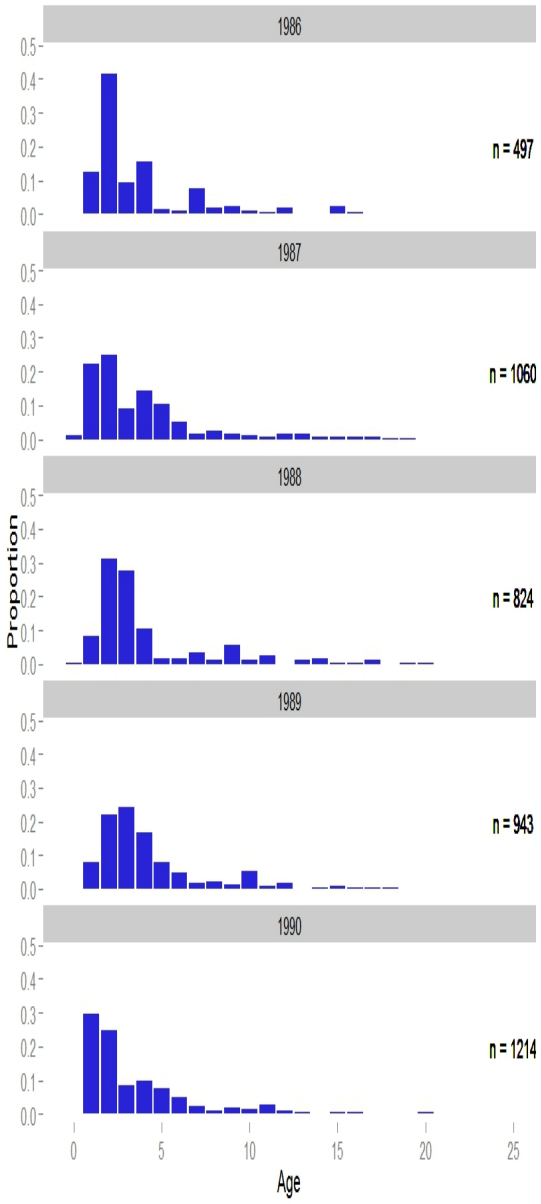
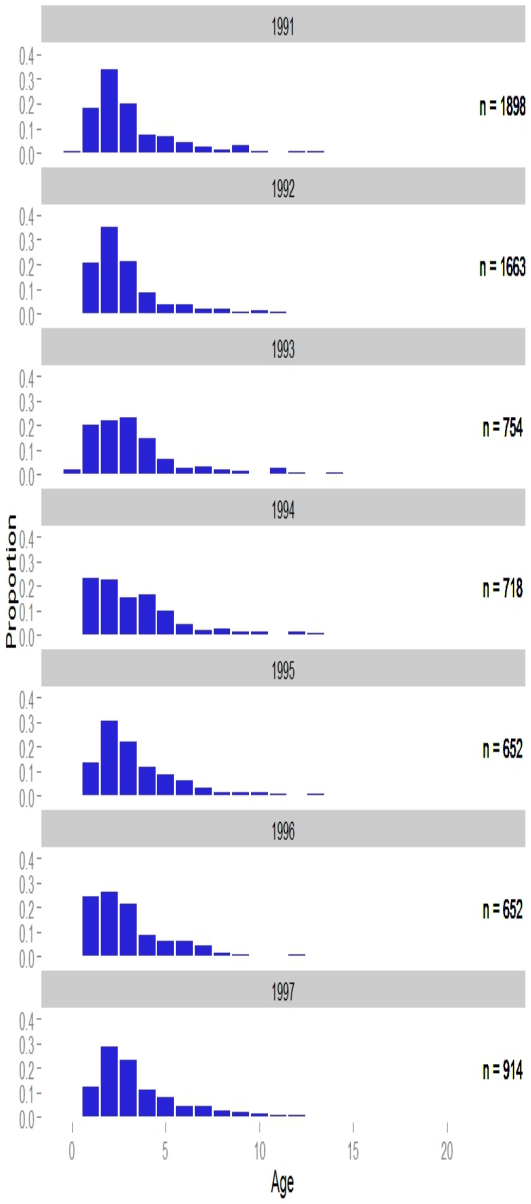


Fig 4 (b). Age frequency distributions for king mackerel age samples collected from charter boat (CP) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1991 and 1997.

(a) GOM



(b) ATL

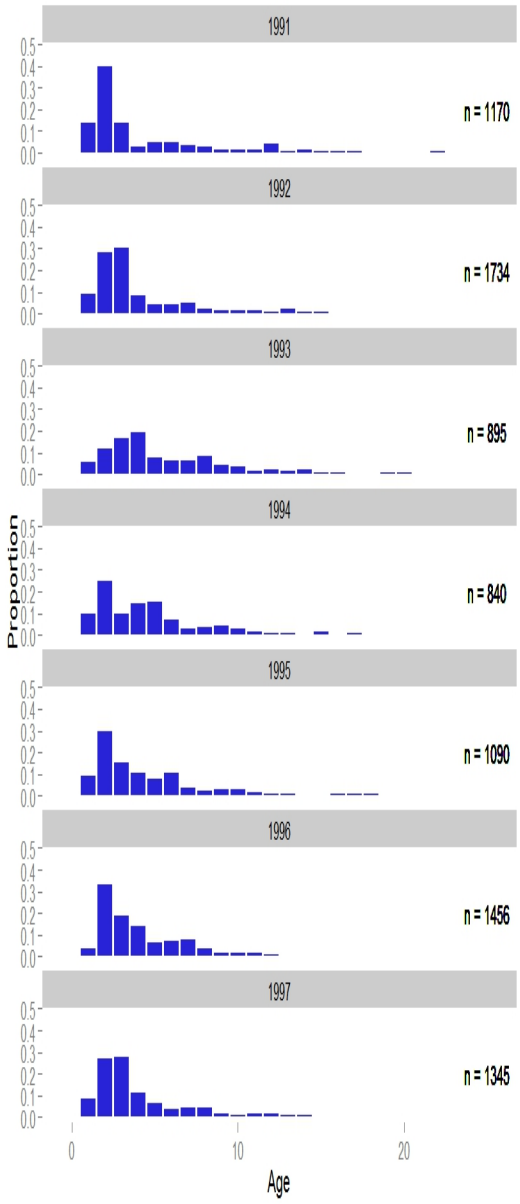
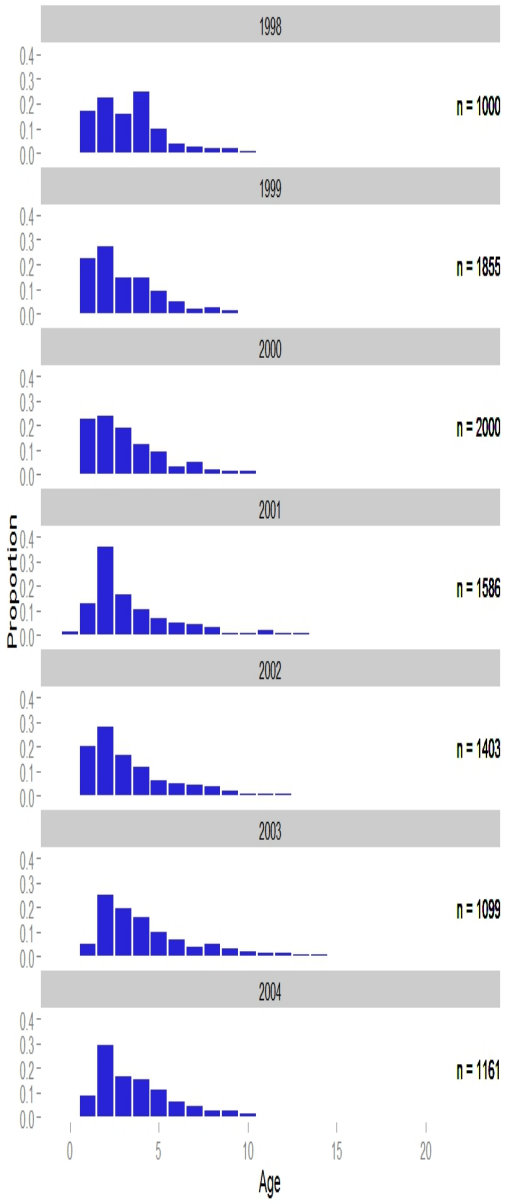


Fig 4 (c). Age frequency distributions for king mackerel age samples collected from charter boat (CP) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1998 and 2004.

(a) GOM



(b) ATL

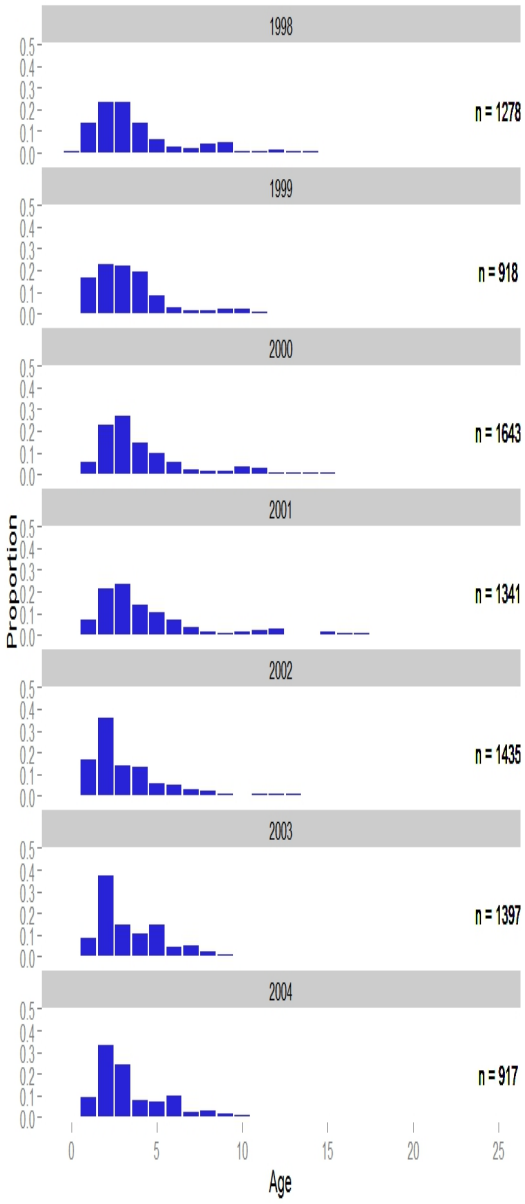
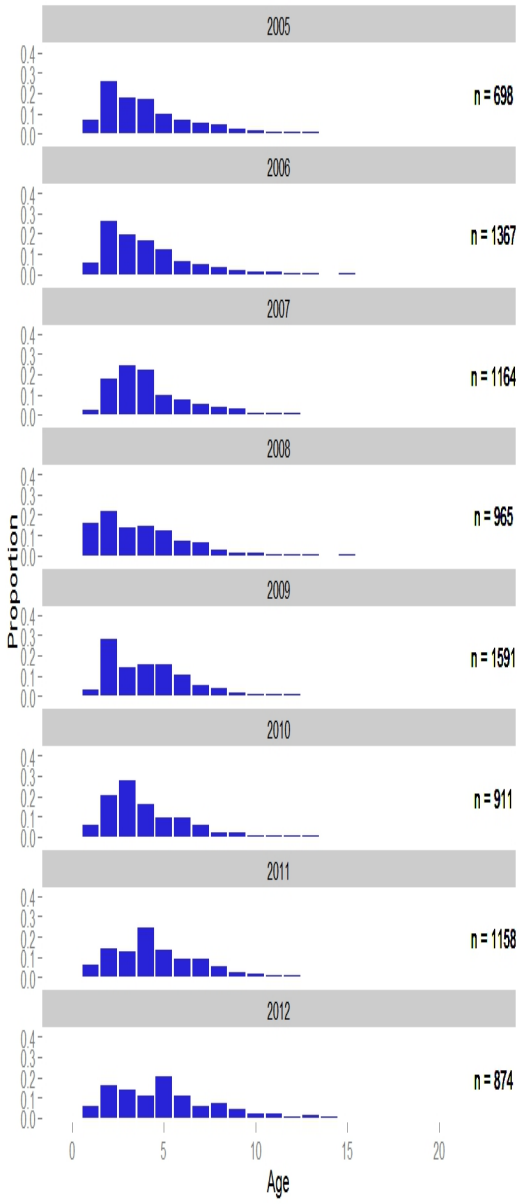


Fig 4 (d). Age frequency distributions for king mackerel age samples collected from charter boat (CP) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 2005 and 2012.

(a) GOM



(b) ATL

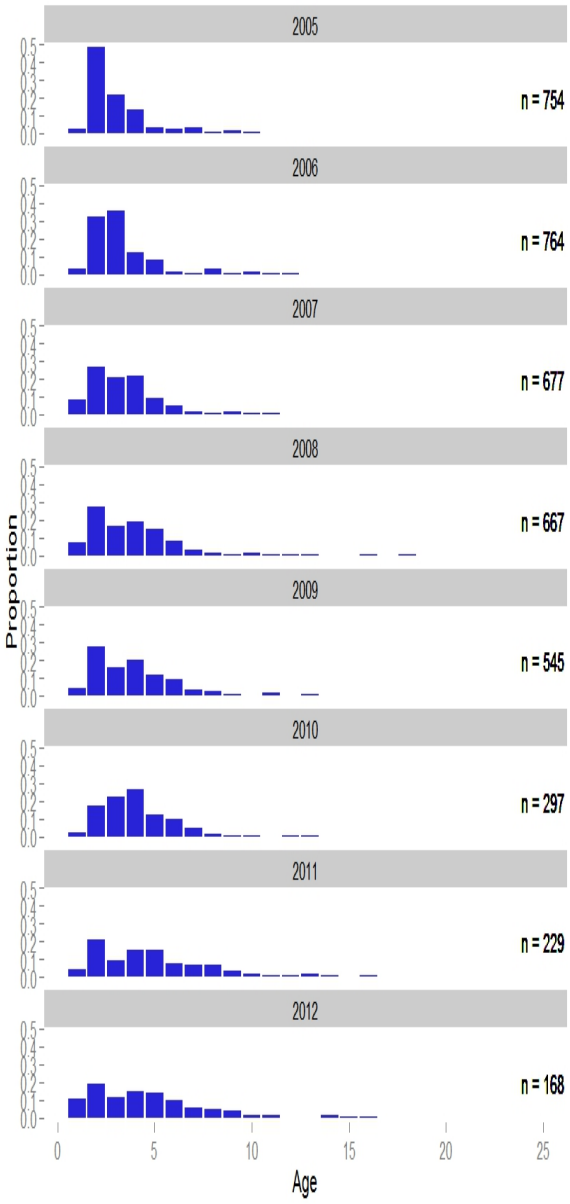
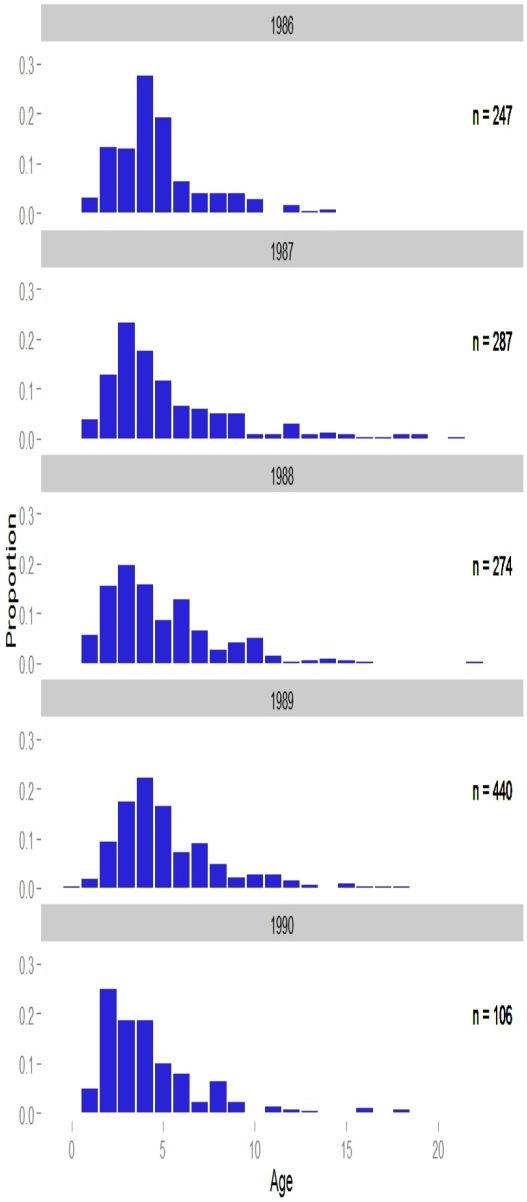


Fig 5 (a). Age frequency distributions for king mackerel age samples collected from head boat (HB) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1986 and 1990.

(a) GOM



(b) ATL

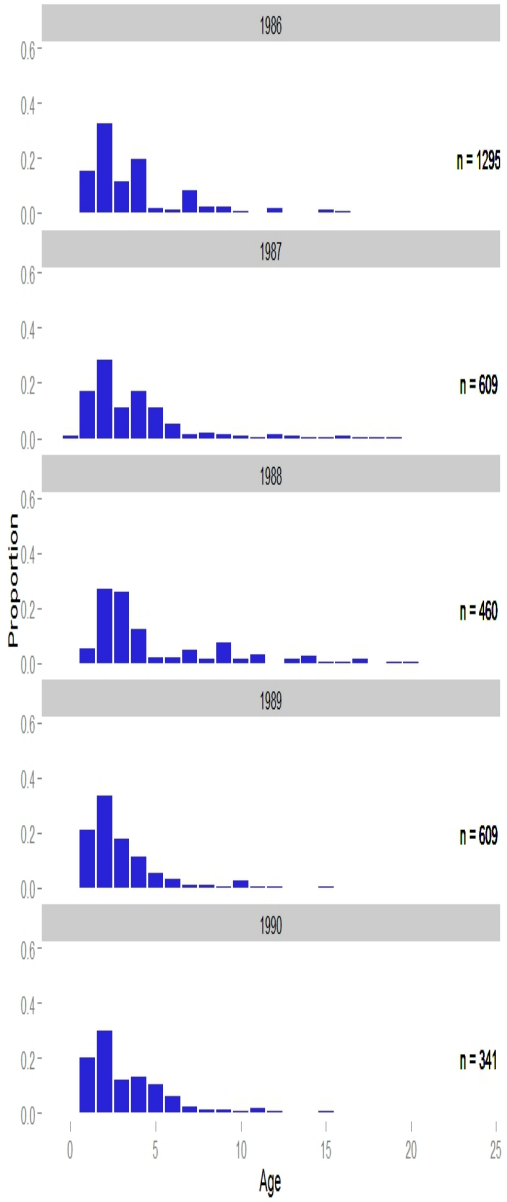
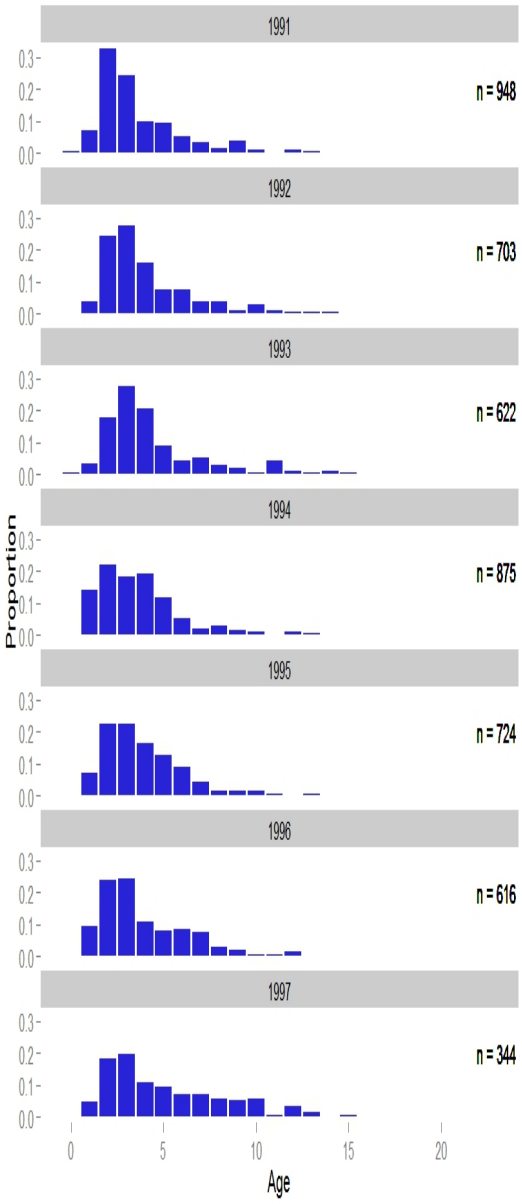


Fig 5 (b). Age frequency distributions for king mackerel age samples collected from head boat (HB) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1991 and 1997.

(a) GOM



(b) ATL

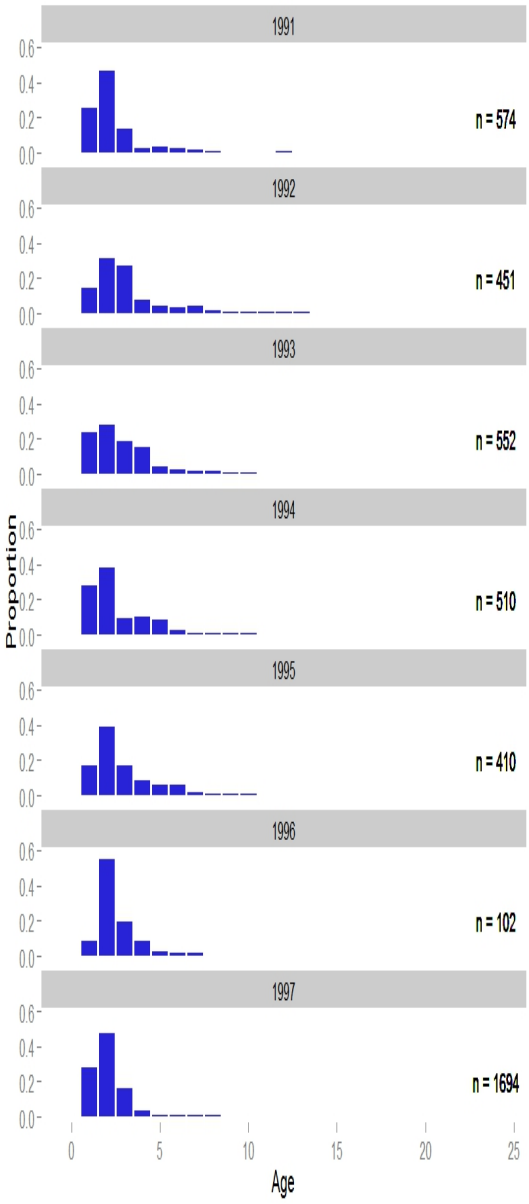
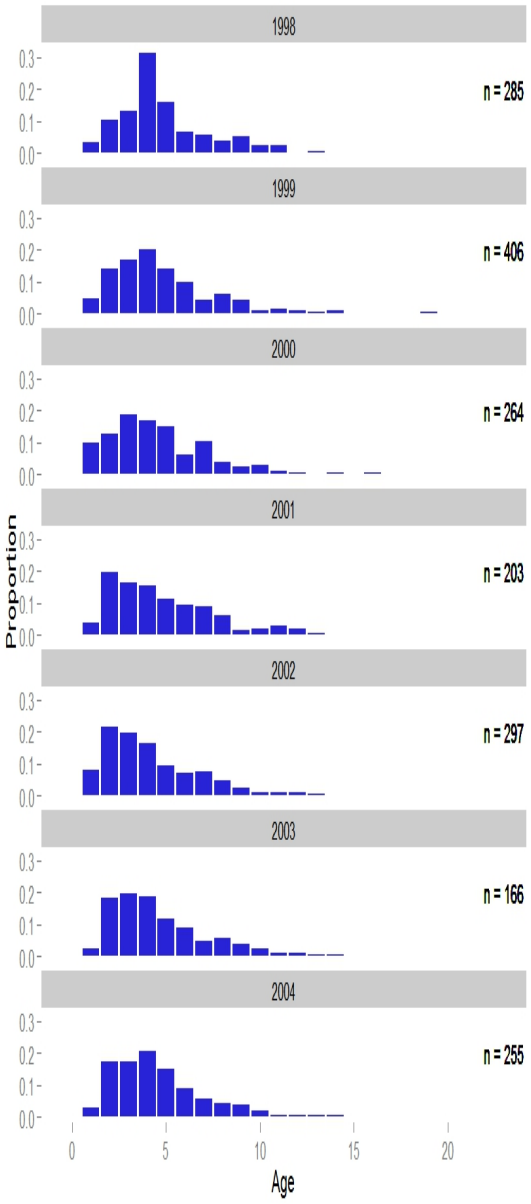


Fig 5 (c). Age frequency distributions for king mackerel age samples collected from head boat (HB) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1998 and 2004.

(a) GOM



(b) ATL

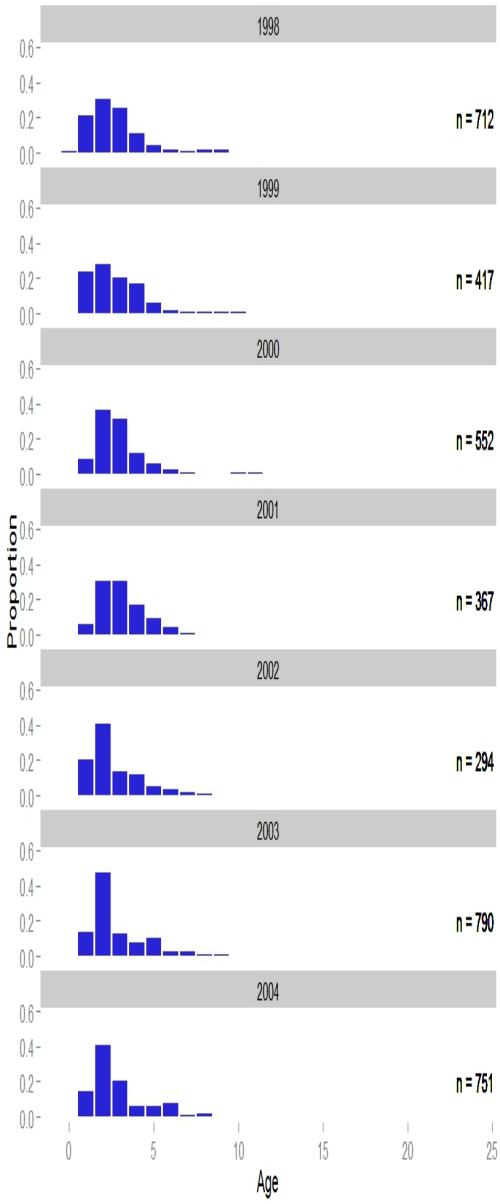
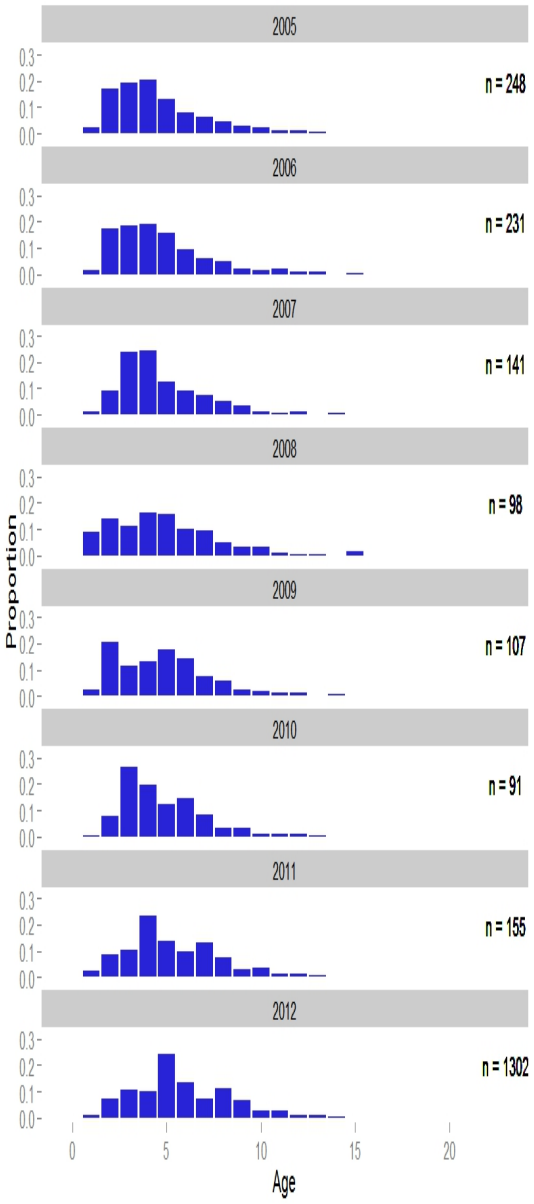


Fig 5 (d). Age frequency distributions for king mackerel age samples collected from head boat (HB) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 2005 and 2012.

(a) GOM



(b) ATL

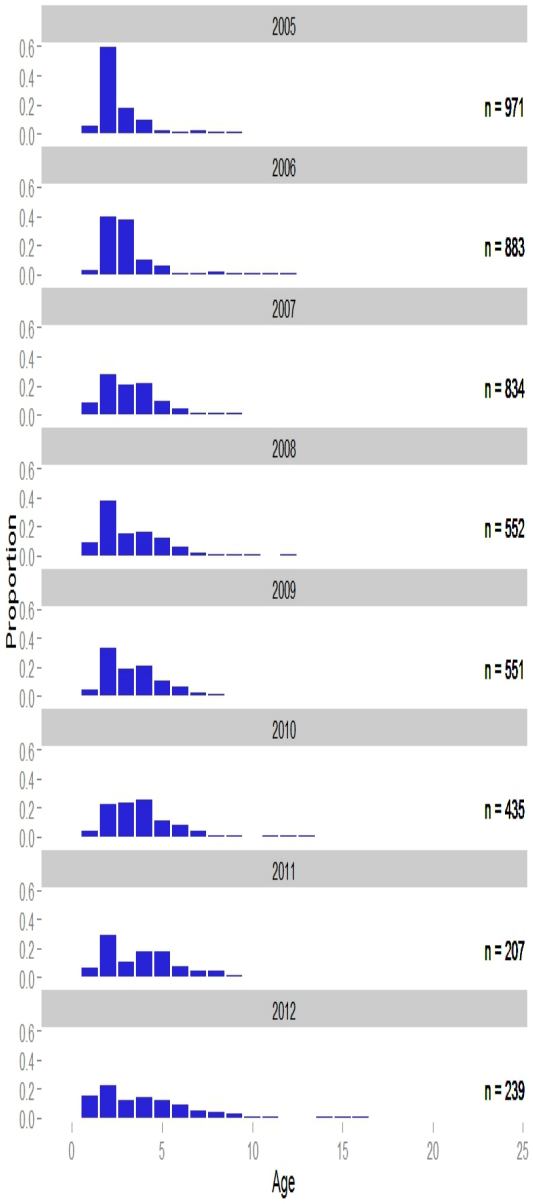
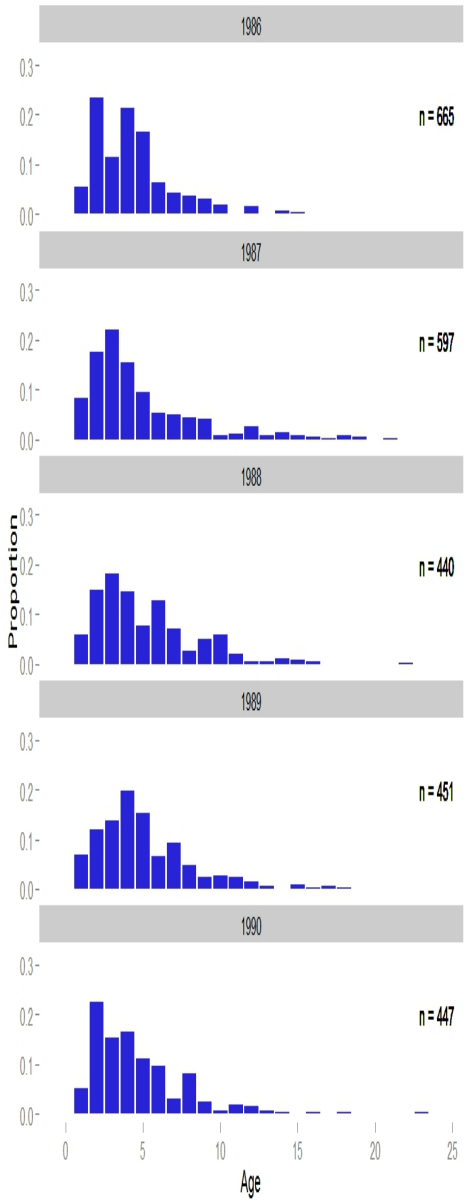


Fig 6 (a). Age frequency distributions for king mackerel age samples collected from private boat (PR) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1986 and 1990.

(a) GOM



(b) ATL

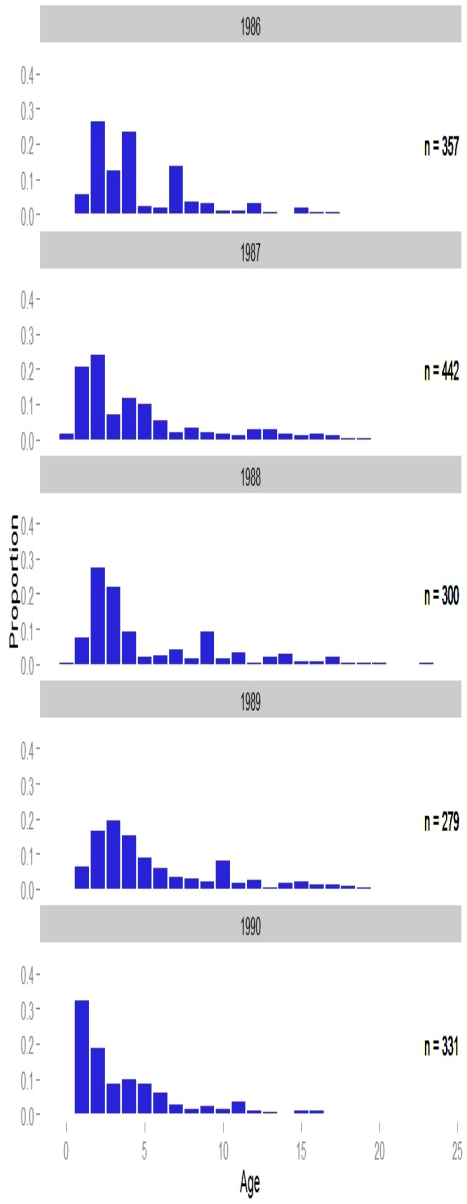
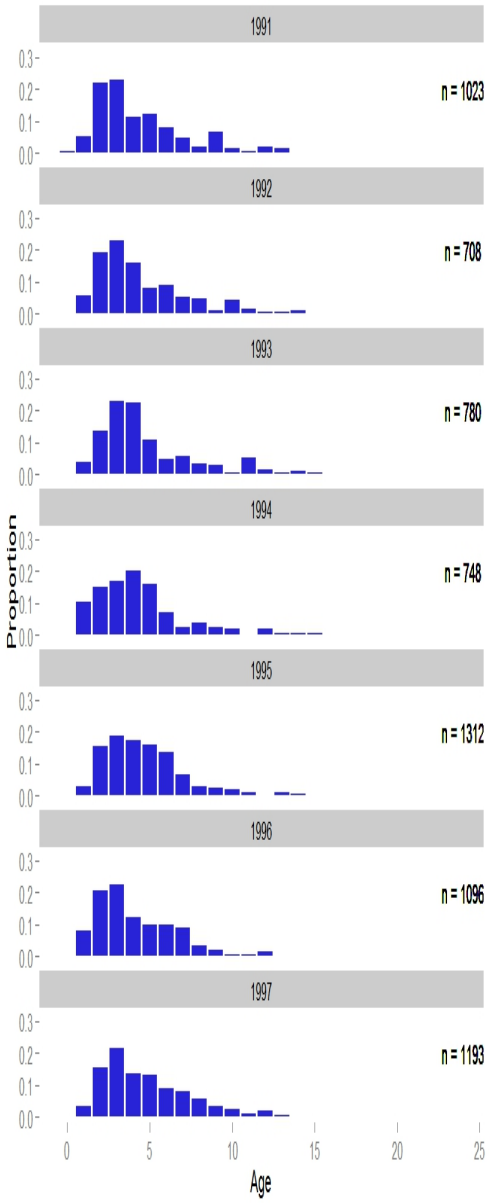


Fig 6 (b). Age frequency distributions for king mackerel age samples collected from private boat (PR) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1991 and 1997.

(a) GOM



(b) ATL

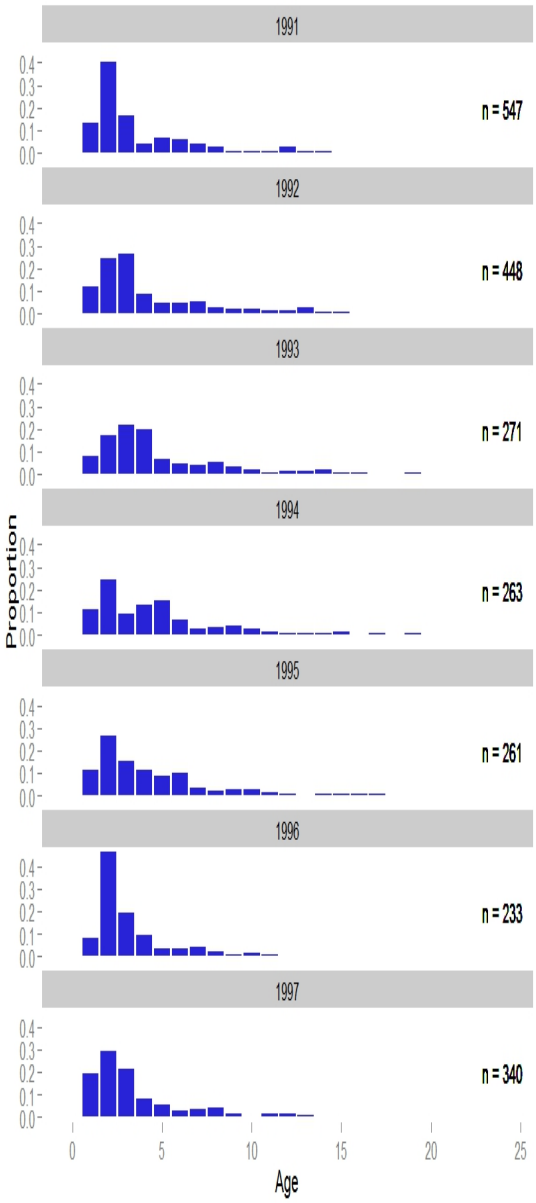
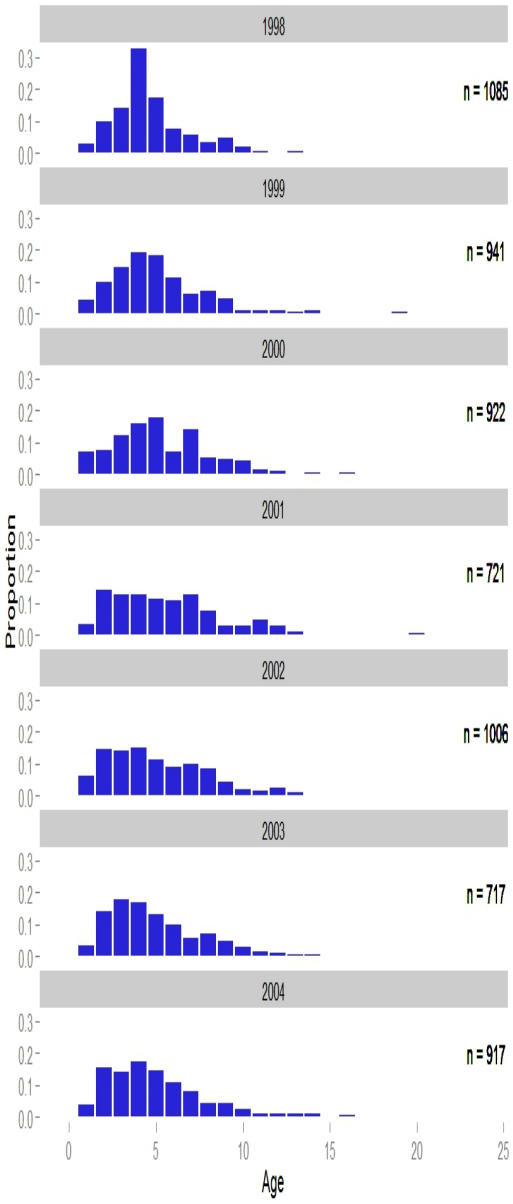


Fig 6 (c). Age frequency distributions for king mackerel age samples collected from private boat (PR) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1998 and 2004.

(a) GOM



(b) ATL

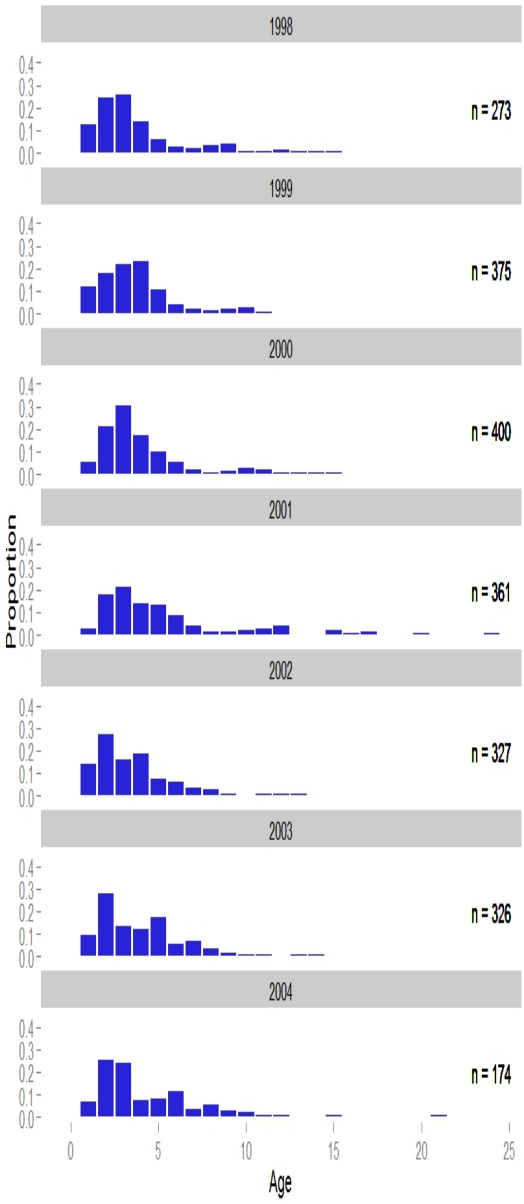
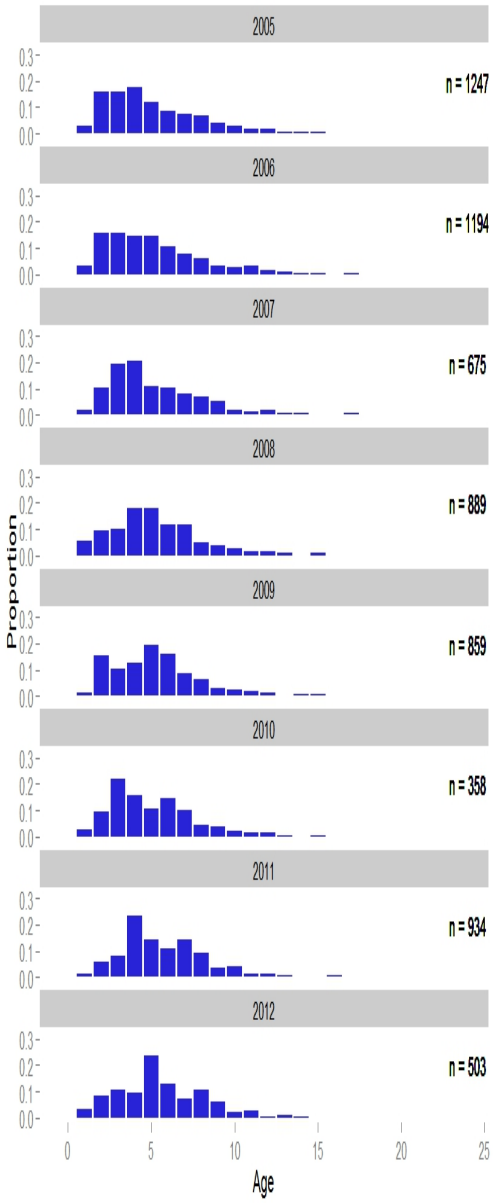


Fig 6 (d). Age frequency distributions for king mackerel age samples collected from private boat (PR) fisheries from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 2005 and 2012.

(a) GOM



(b) ATL

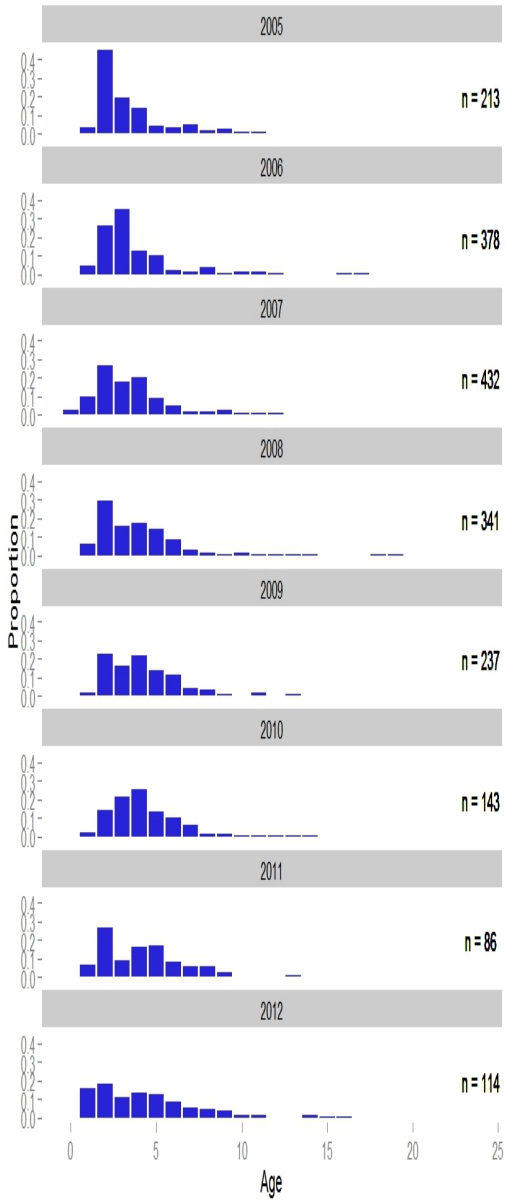
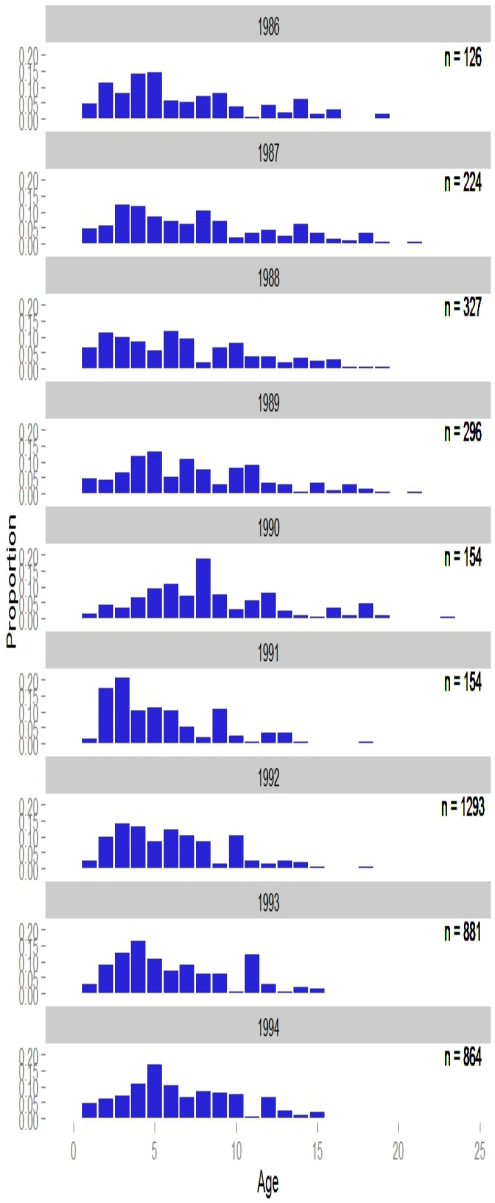


Fig 7 (a). Age frequency distributions for king mackerel age samples collected from tournament fishing (TRN) from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1986 and 1994.

(a) GOM



(b) ATL

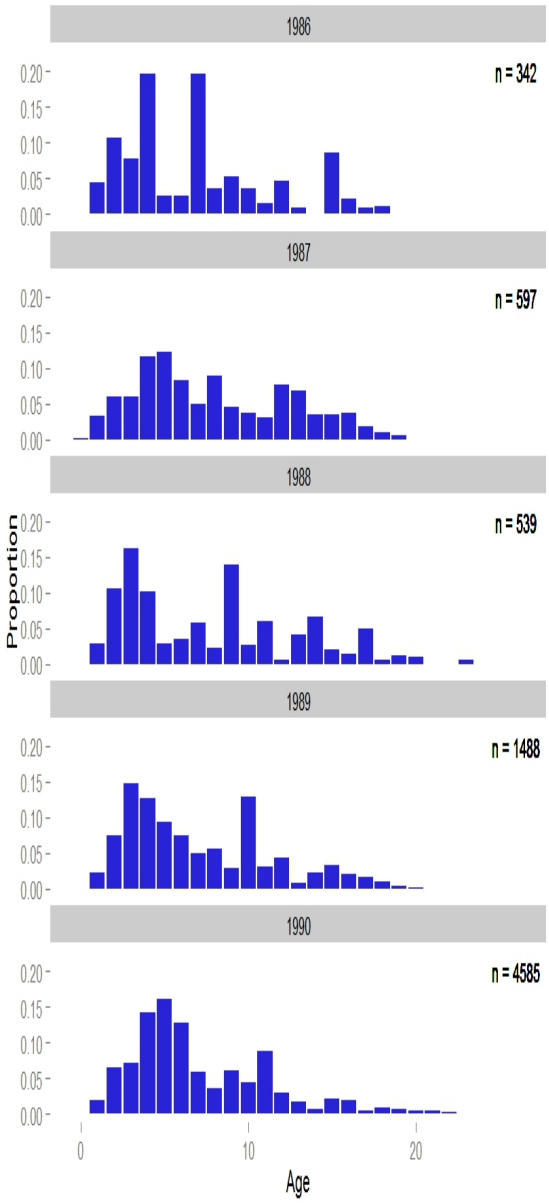
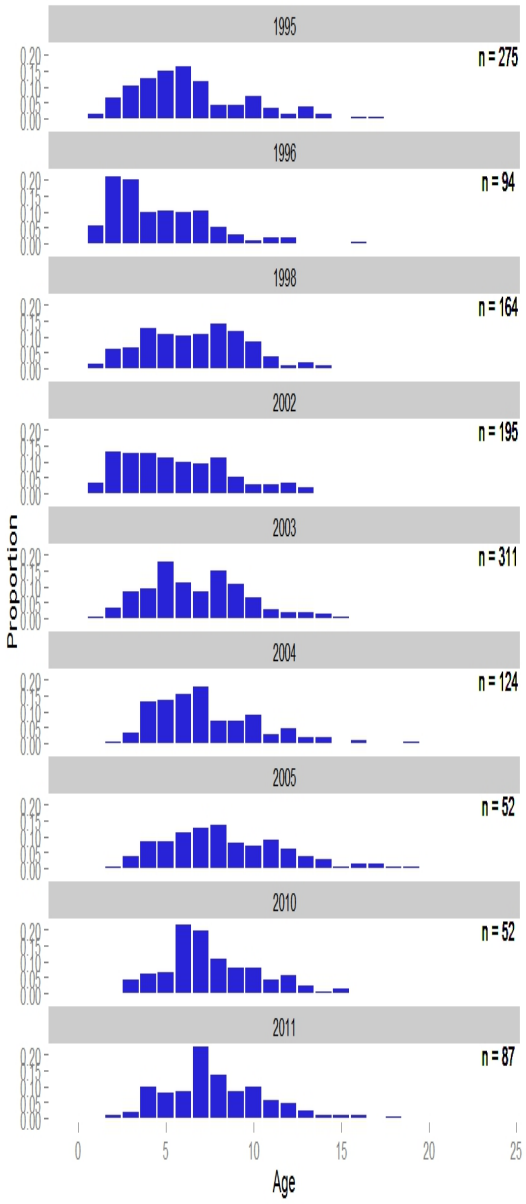


Fig 7 (b). Age frequency distributions for king mackerel age samples collected from tournament fishing (TRN) from (a) the Gulf of Mexico (GOM) stock and (b) the Atlantic (ATL) stock between 1991 and 2011.

(a) GOM



(b) ATL

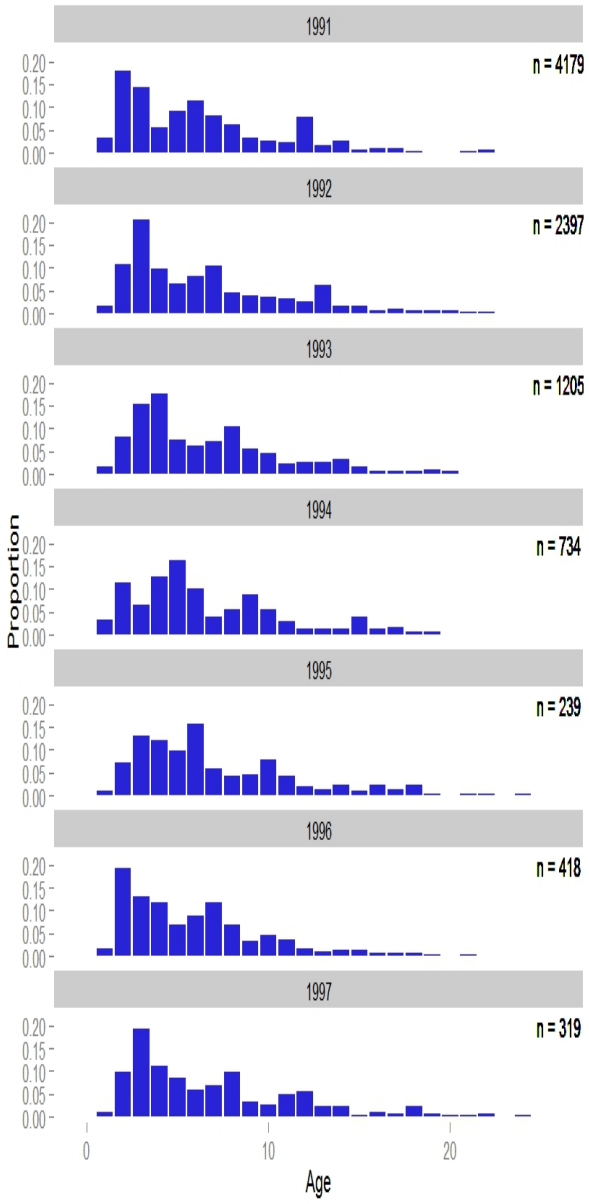
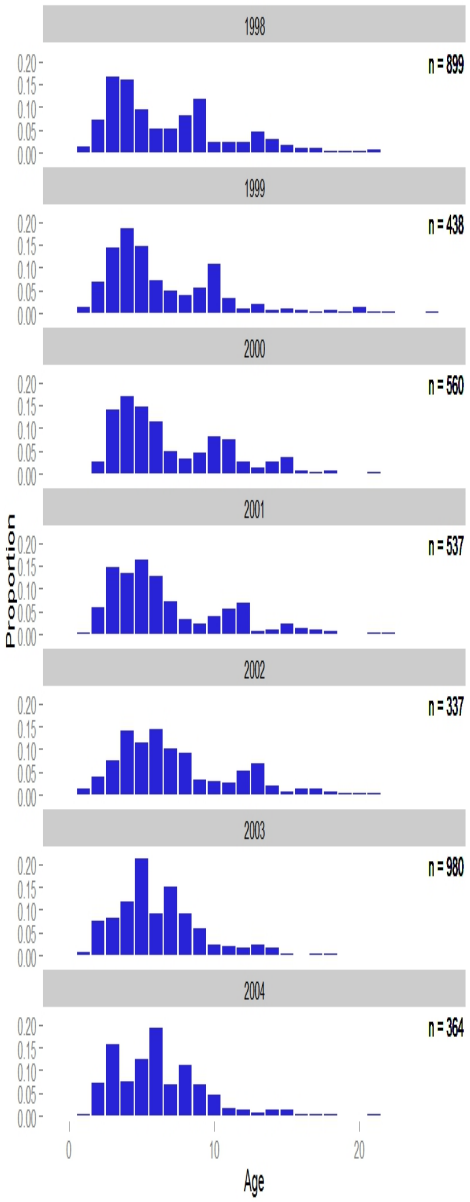


Fig 7 (c). Age frequency distributions for king mackerel age samples collected from tournament fishing (TRN) from the Atlantic (ATL) stock between 1998 and 2012.

(a) ATL



(b) ATL

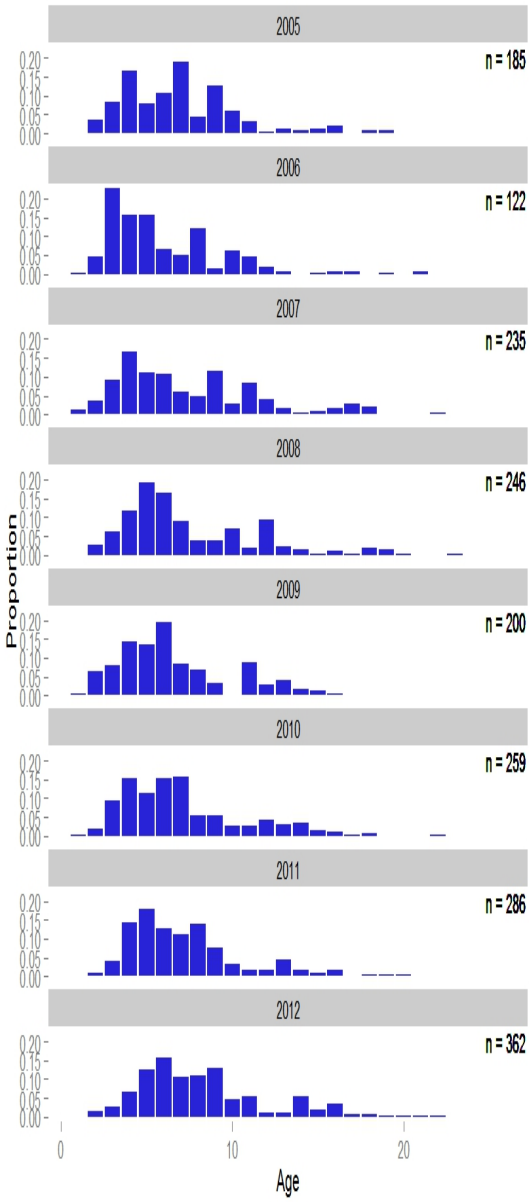


Table 3. Sample sizes, lengths at ages (LAA) and standard deviations (STD) of lengths at ages for age samples collected from the GOM and the ATL stocks from 1986 to 2012.

Age	n_ATL	LAA_ATL	STD_ATL	n_GOM	LAA_GOM	STD_GOM
0	14	46.42	10.19	38	50.24	9.98
1	1588	63.81	8.72	2338	61.38	6.90
2	6273	71.64	7.22	5239	71.03	6.20
3	5390	79.20	6.76	4638	77.53	7.36
4	4270	84.30	8.05	4421	81.91	8.52
5	3260	89.10	9.04	3497	86.47	10.01
6	2344	94.21	10.11	2554	90.21	11.43
7	1558	98.65	10.95	1958	93.85	12.78
8	1240	101.98	11.21	1443	96.79	13.58
9	944	105.28	11.81	1005	100.98	14.75
10	762	106.72	12.26	661	105.05	15.36
11	602	108.09	11.81	470	107.58	16.09
12	483	110.09	13.32	382	109.27	16.19
13	376	111.42	12.55	233	111.30	16.47
14	299	113.71	13.18	145	114.86	17.35
15	263	114.40	13.63	99	116.46	16.58
16	182	113.88	12.92	55	118.14	18.03
17	134	115.52	13.47	31	124.89	17.39
18	107	118.89	14.04	35	126.34	14.83
19	68	121.19	12.90	15	126.87	18.45
20	42	122.90	13.78	7	130.03	15.99
21	32	120.71	16.37	5	128.46	14.34
22	26	125.35	13.57	2	111.75	2.47
23	3	124.50	18.19	1	101.00	
24	6	126.33	13.53	1	144.00	
25	2	138.25	4.60			
26	1	137.00				

Fig 8. Lengths at ages for age samples collected from the GOM and the ATL stocks.

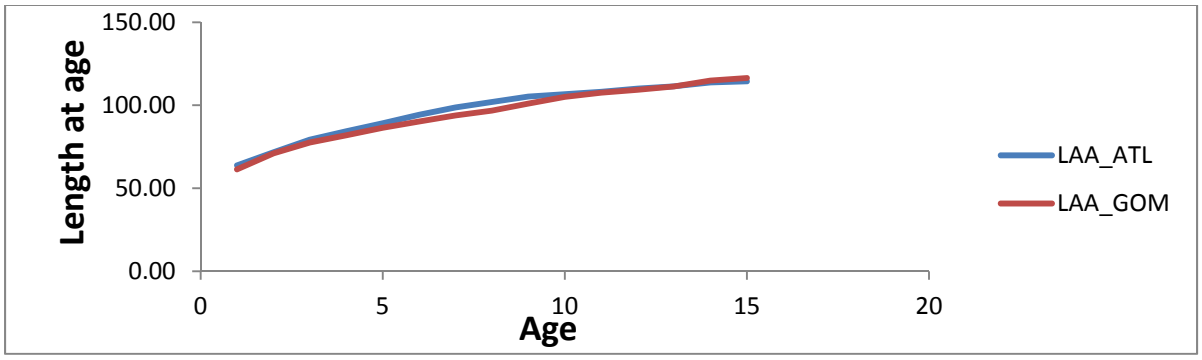
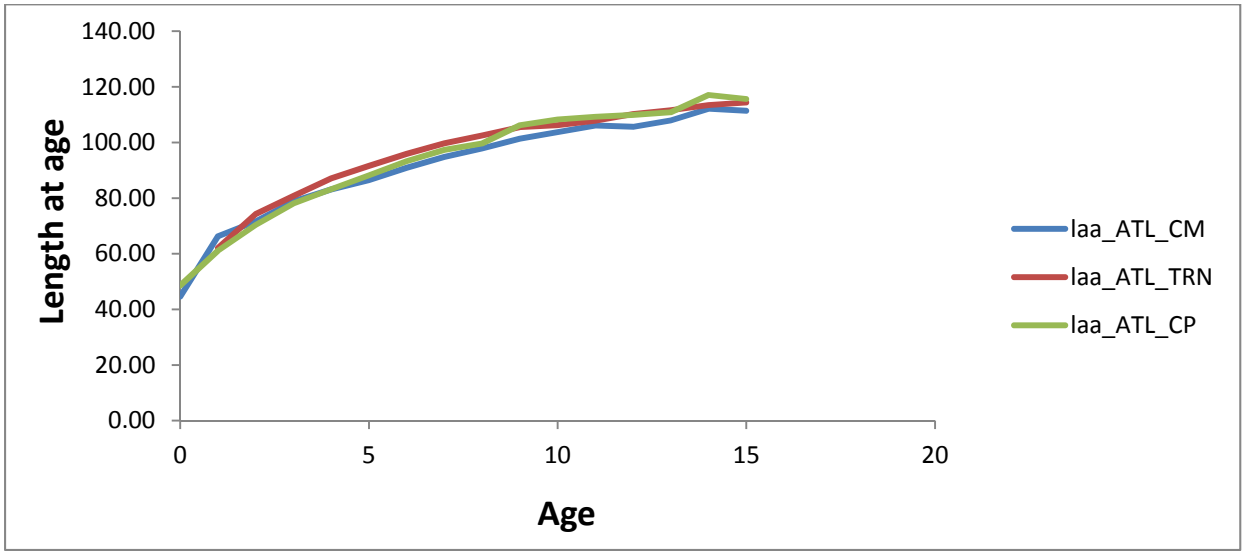


Fig 9. Lengths at ages for age samples collected from different fisheries in the ATL and the GOM stocks (CM-commercial, TRN-tournament, CP- charter boat).

(a) ATL



(b) GOM

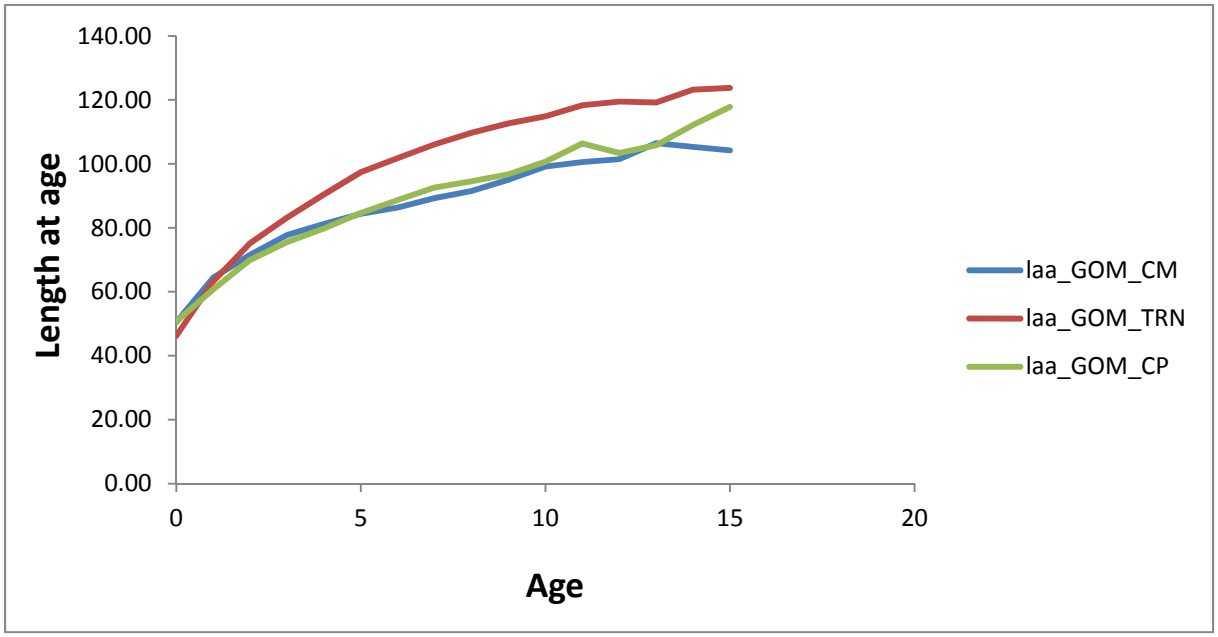
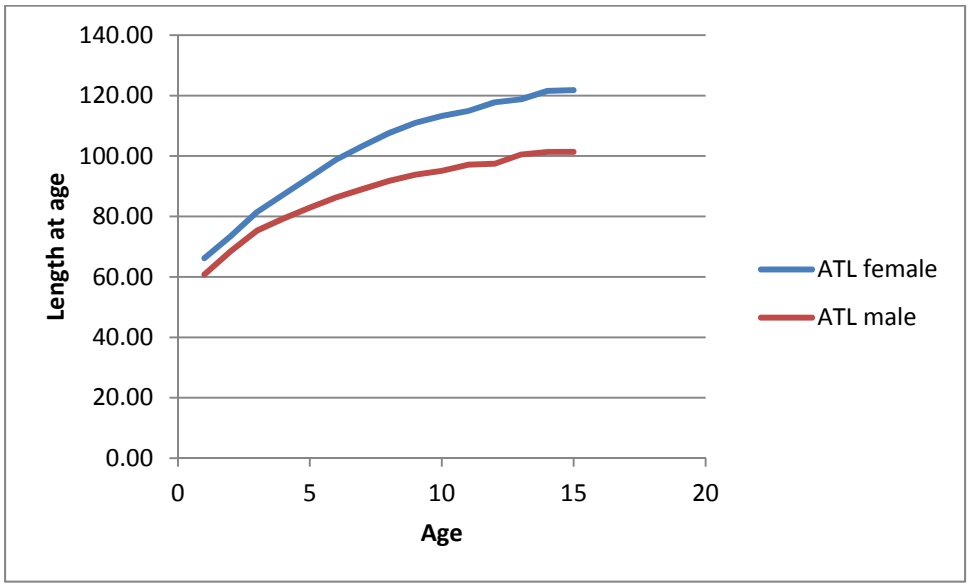


Fig 10. Differences in lengths at ages for female and male age samples collected from the ATL and the GOM stocks.

(a) ATL



(b) GOM

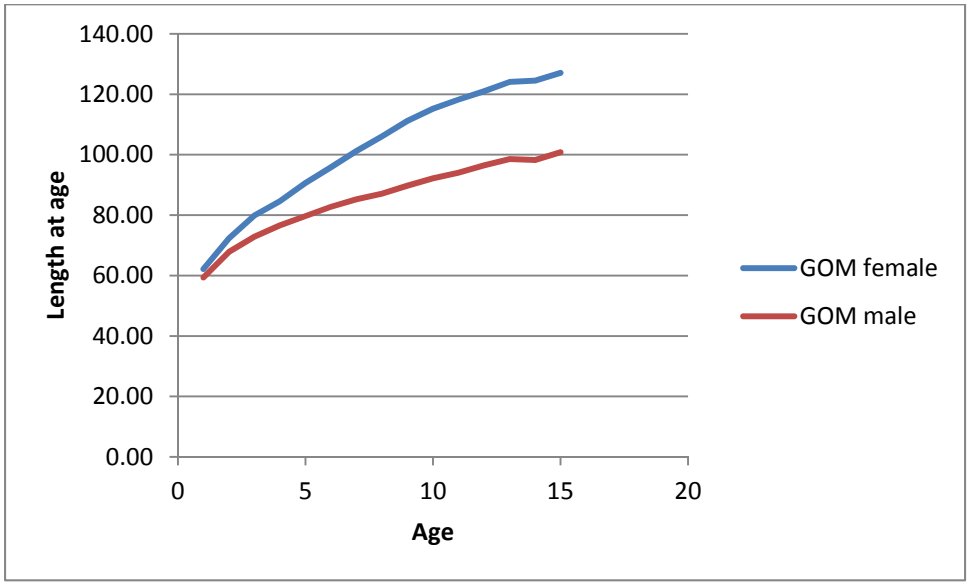
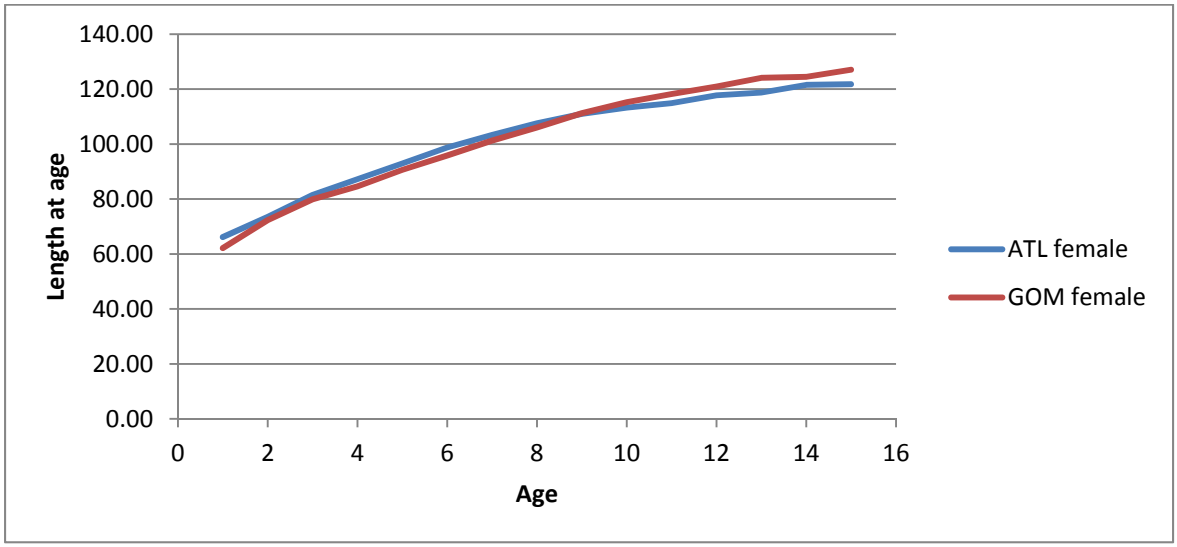


Fig 11. Same sex comparisons of lengths at ages for female and male age samples collected from the ATL and the GOM stocks.

(a) Female



(b) Male

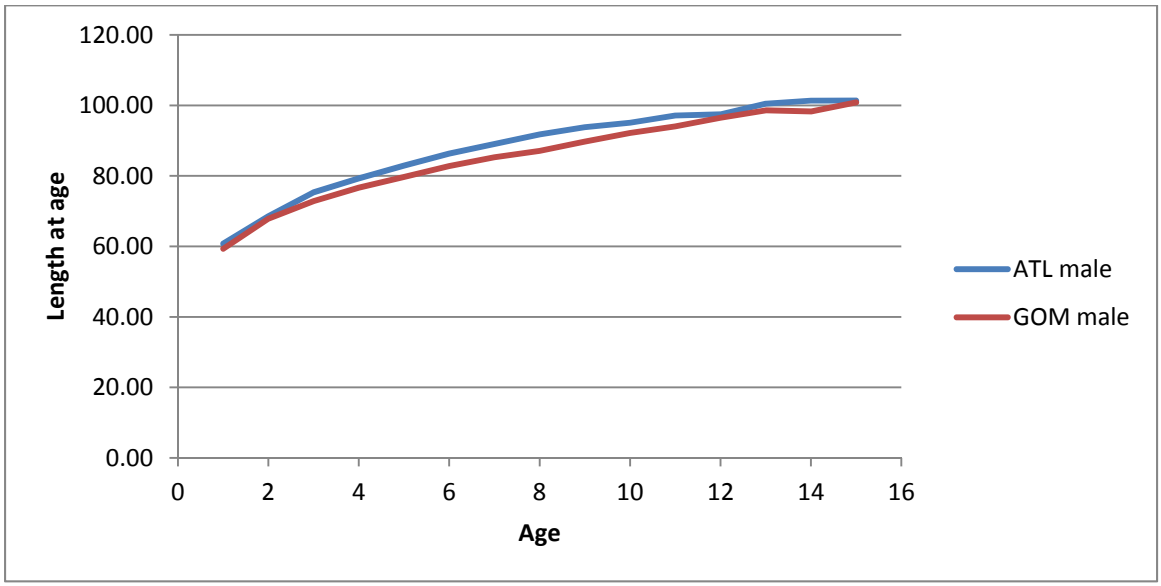


Table 4(a). Sample sizes and sex ratios (m/f) for age samples collected from different modes of fisheries from 1986 to 2013 (CM-commercial, CP- charter boat, HB- head boat, PR- private boat, SH- shore, TRN-tournament).

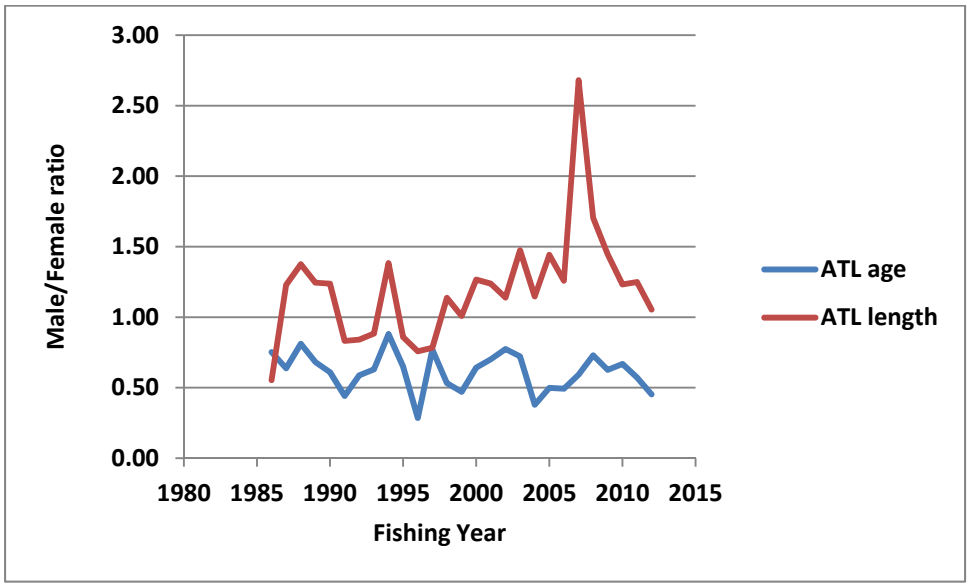
	ATL					GOM			
Mode	F		M	U	m/f	F	M	U	m/f
CM		8767	5900	42	0.67	7458	5558	80	0.75
CP		1512	1501	8	0.99	5587	2820	181	0.50
HB		332	359	8	1.08	738	555	18	0.75
PR		1139	280	16	0.25	1177	587	167	0.50
SH						29	2	1	0.07
TRN		7298	3098	9	0.42	3444	866	5	0.25
Grand Total		19048	11138	83	0.58	18433	10388	452	0.56

Table 4 (b). Sample sizes and sex ratios (m/f) for length samples collected from commercial fisheries from 1983 to 2013.

Mode	F		M	U	m/f	F	M	U	m/f
Commercial		67349	74957	52611	1.11	41635	31817	18439	0.76

Fig 12. Changes in sex ratios (male/female) for commercial age and length samples collected from the ATL and the GOM stocks from 1986 to 2012.

(a) ATL



(b) GOM

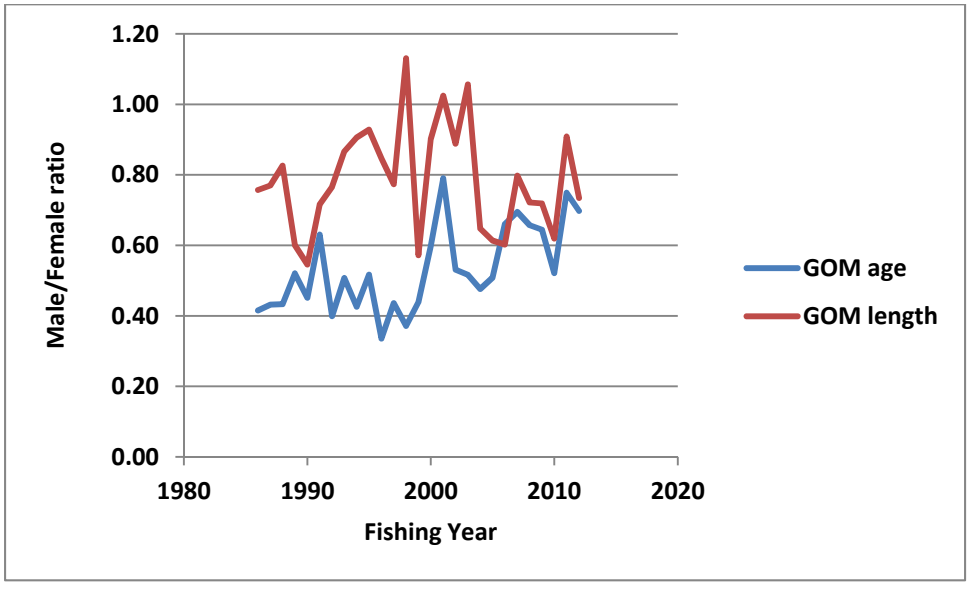


Table 5. Sample sizes and sex ratios (m/f) for length samples collected from commercial fisheries for different months from 1983 to 2013.

	ATL			GOM		
Month	No. female	No. Male	m/f	No. Female	No. Male	m/f
1	7107	4822	0.68	7723	6026	0.78
2	5248	4786	0.91	5732	5055	0.88
3	4673	5835	1.25	2723	2308	0.85
4	5169	10211	1.98	735	1122	1.53
5	8198	16188	1.97	276	477	1.73
6	5372	7142	1.33	598	908	1.52
7	3456	3848	1.11	7184	6009	0.84
8	8137	8804	1.08	4952	3918	0.79
9	3460	3489	1.01	2112	1401	0.66
10	2896	2909	1.00	2539	929	0.37
11	3257	1980	0.61	2190	820	0.37
12	10376	4943	0.48	4871	2844	0.58

Fig 13. Changes in sex ratios (m/f) for length samples collected from commercial fisheries for different months.

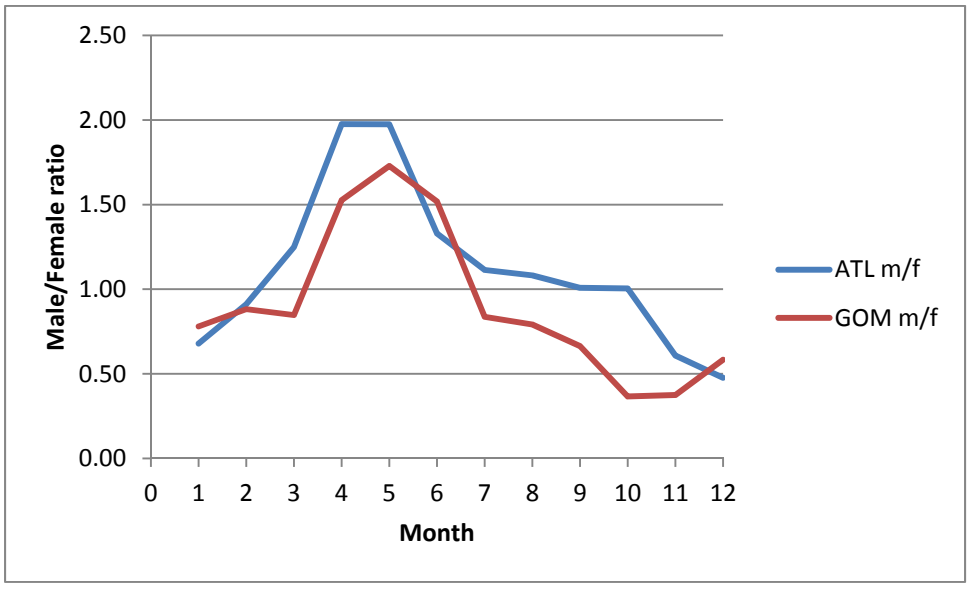


Table 6. Sample sizes and sex ratios (m/f) for age samples collected from commercial fisheries for different months from 1986 to 2013.

	ATL			GOM		
Month	No. female	No. Male	m/f	No. Female	No. Male	m/f
1	1681	1200	0.71	720	621	0.86
2	997	568	0.57	724	595	0.82
3	1146	843	0.74	59	84	1.42
4	516	533	1.03	128	77	0.60
5	517	574	1.11	21	12	0.57
6	497	499	1.00	40	15	0.38
7	408	377	0.92	2395	2103	0.88
8	302	226	0.75	1382	1095	0.79
9	183	143	0.78	521	328	0.63
10	166	95	0.57	945	383	0.41
11	474	202	0.43	347	118	0.34
12	1880	640	0.34	176	127	0.72

Fig 14. Sample sizes and sex ratios (m/f) for age samples collected from commercial fisheries for different months from 1986 to 2013.

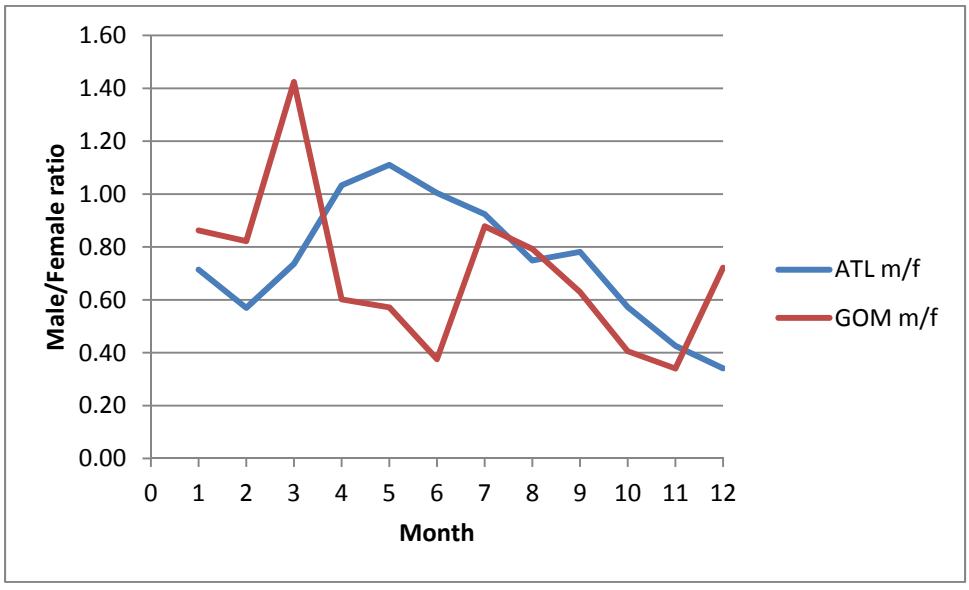
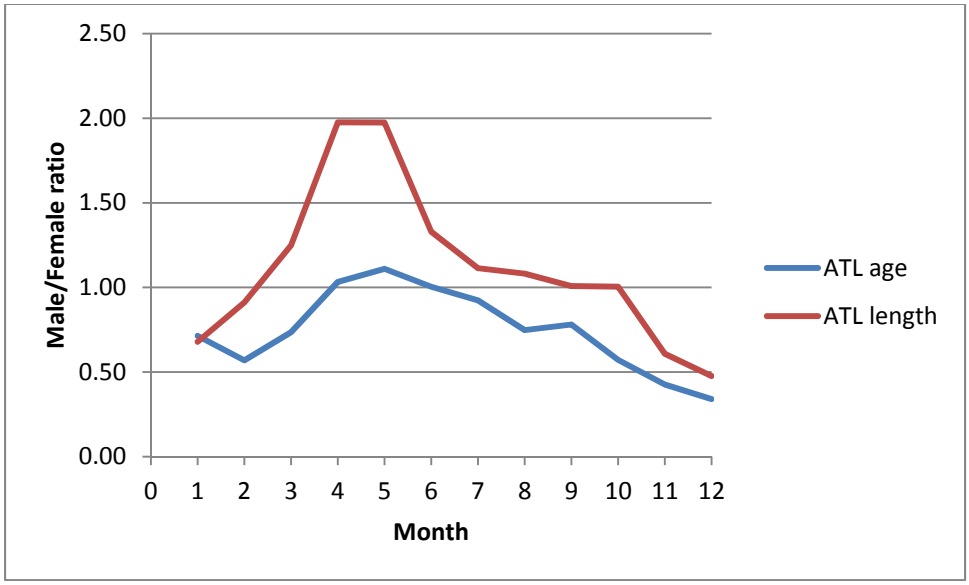


Fig 15. Sample sizes and sex ratios (m/f) for age and length samples collected from commercial fisheries in the ATL and the GOM stocks for different months from 1986 to 2013.

(a) ATL



(b) GOM

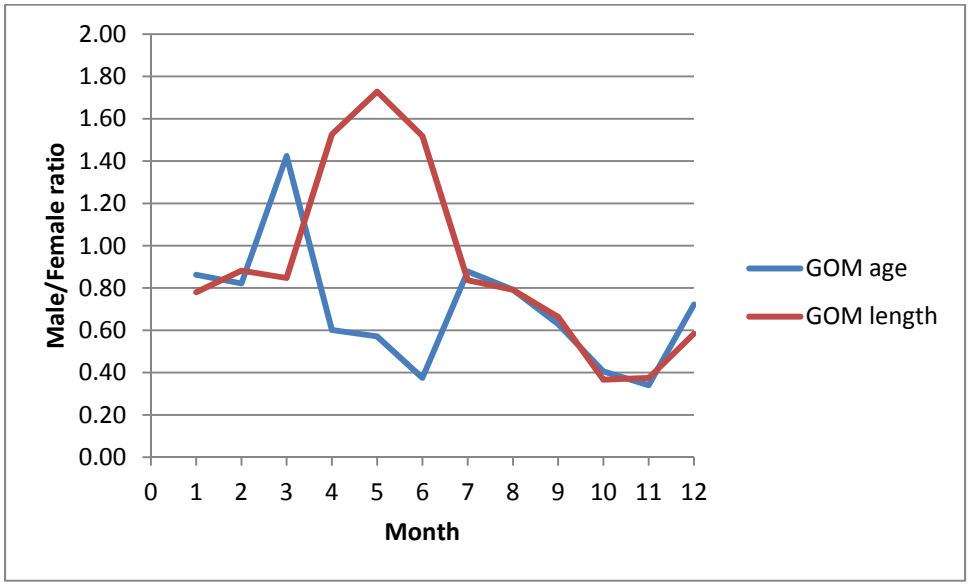


Table 7. Number of female and male fish at different length intervals for length samples collected from commercial fisheries from 1983 to 2013.

	ATL		GOM	
Length	**F**	**M**	**F**	**M**
25		1	2	1
30	1	1		2
35	1	1	3	
40	3	12	7	5
45	19	84	23	18
50	172	467	58	84
55	1040	2037	304	264
60	3362	5830	1335	1550
65	6128	8981	2866	3416
70	9806	12881	4718	5143
75	12194	14657	5559	5865
80	10983	13051	5981	5769
85	8896	9397	5523	4384
90	5965	4661	4923	2833
95	3713	1841	3788	1558
100	2273	717	2661	586
105	1310	201	1618	207
110	732	72	886	77
115	382	40	519	32
120	178	17	335	12
125	119	3	243	7
130	48	3	134	2
135	18	2	79	
140	3		42	1
145	3		21	1
150			5	
155			1	
175			1	
Grand Total	**67349**	**74957**	**41635**	**31817**

Fig 16. Sex ratios (m/f) by size for commercial length samples collected from the ATL and the GOM stocks from 1983 to 2013.

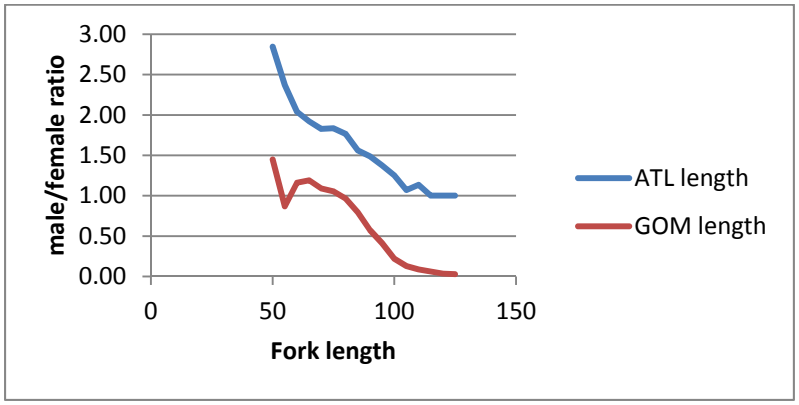


Table 8. Number of female and male fish at different length intervals for age samples collected from 1986 to 2013.

	ATL		GOM	
Row Labels	**F**	**M**	**F**	**M**
30	1		1	
35	2	4	5	1
40	6	10	13	5
45	34	43	63	39
50	67	71	159	88
55	203	212	444	250
60	655	772	950	593
65	1044	1004	1563	1160
70	1779	1829	2170	1759
75	2154	1975	2433	2005
80	2588	1725	2481	1812
85	2251	1252	1959	1288
90	1685	926	1543	718
95	1411	550	1072	326
100	1195	427	842	167
105	1081	195	691	90
110	912	93	560	39
115	734	36	504	28
120	571	13	392	12
125	370	1	265	5
130	182		176	2
135	81		77	
140	23		39	1
145	12		25	
150	7		3	
155			2	
170			1	
Grand Total	**19048**	**11138**	**18433**	**10388**

Fig 17. Sex ratios (m/f) by size for age samples collected from the ATL and the GOM stocks from 1986 to 2013.

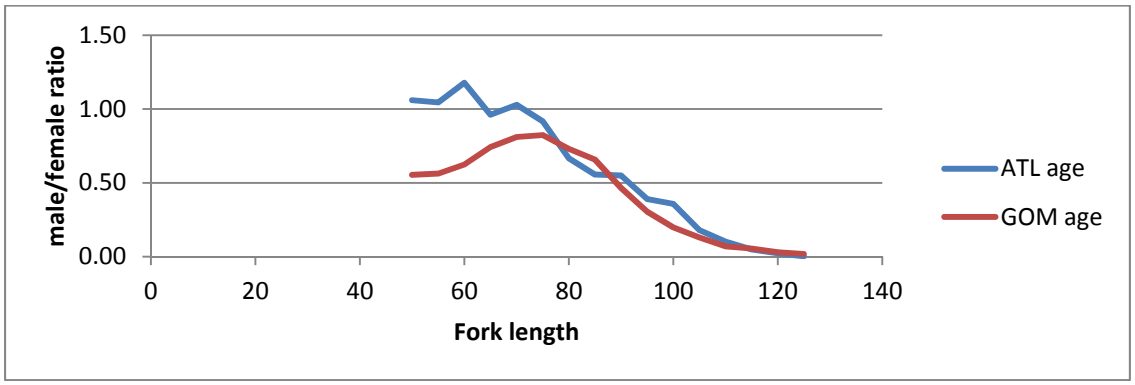
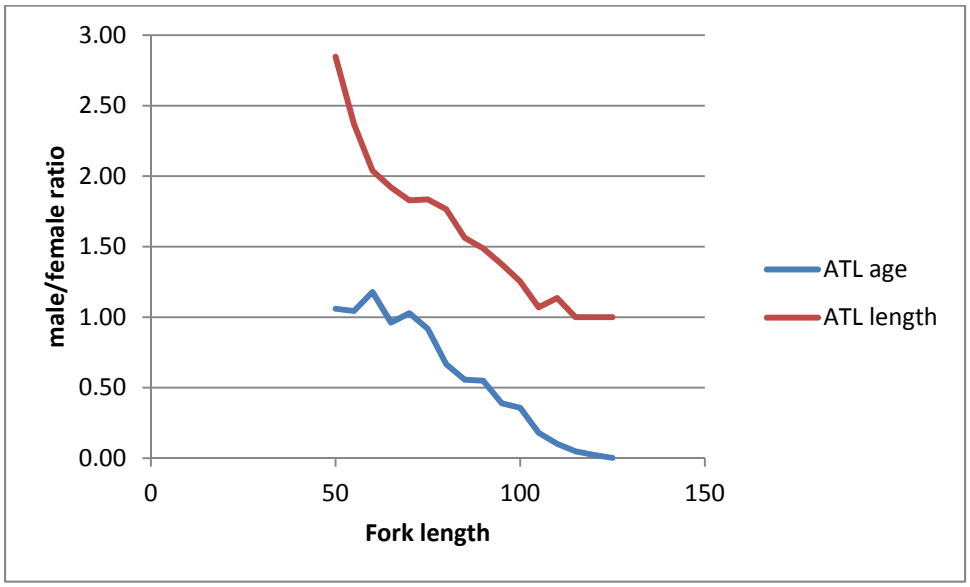


Fig18. Sex ratios (m/f) by size for age and length samples collected from the ATL and the GOM stocks.

(a) ATL



(b) GOM