Updated South Coast rock lobster stock assessments for 2009

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Introduction

This document is submitted in response to the requirement that "simple routine updated assessments (likely no more than core reference set models used in the OMP testing refitted taking a further year's data into account)" be tabled every year an OMP is in operation for a fishery (MCM, 2007)

This document reports such updated stock assessments for the South Coast rock lobster fishery. Essentially two further years' CPUE and catch-at-length data are available since the assessments upon which OMP testing was based were carried out in 2008 (see Johnston and Butterworth 2008a). Although Johnston and Butterworth (2008a) initially presented stock assessment results for a wide range of models, only Models 3 and 4 were used as a final Reference Set in final OMP deliberations. Updates of Models 3 and 4 are thus presented here. To recap:

Model 3 – assumes time-varying selectivity using the MARAM method
Model 4 – assumes time-varying selectivity using the OLRAC method.

Besides data updates, a further update to these assessment models is that the period for which recruitment residuals are estimated is extended from 1974-1997 by two further seasons to 1974-1999.

Data

The following input data are used in the updated assessment results presented here:
1. Commercial catch data for each Area as reported in Glazer (2009a) – see Table 1.
2. CPUE series for each Area from GLM analyses reported in Glazer (2009b) – see Table 2.
3. Catch-at-length data for each Area and both sexes as reported in Glazer (2009c) – see Table 3.

Results

Updated assessment results for Models 3 and 4 are reported in Tables 4 and 5 respectively. Table 6 compares the 2009 updated estimates with the estimates reported for the previous assessment (Johnston and Butterworth 2008a).

Figure 1 shows the updated Model 3 and Model 4 fits to the observed CPUE data for all three areas. Figure 2a compares Model 3 and Model 4 fits to the averaged catch-at-

length data for Area 1-3 males and females separately. Figures 2b and c compare Model 3 and 4 fits to catch-at-length data for the two new data sets of 2006 and 2007 respectively. Figure 3 compares Model 3 and 4 estimated stock-recruit residuals. Figure 5 shows the time-varying selectivity $\delta_y^{m/f}$ parameter values for Model 3. Figure 6 shows the time-varying $x_y^{m/f}$ parameter values estimated for Model 4. Finally, Figures 7a and b show the median B_{sp} trajectories for Model 3 and 4 respectively as these were estimated in 2008. The 2009 updated assessment trajectories are also illustrated on these plots for comparison.

Discussion

Updates assessment results (Tables 4 and 5) for Models 3 and 4 report similar goodness of fit to the CPUE data. The best fit continues to be to the Area 1 CPUE data. However, the fits to the catch-at-length (CAL) data for the 2009 updated assessments have deteriorated. For both Model 3 and 4 this is due to the very poor fit to the 2006 catch-at-length data. Figure 2a shows that on average the models fit well to the catch-at-length data. The problem appears to be contained to the 2006 year for which a relatively small sample size was obtained (Glazer 2009c), with atypical results for both cases for Areas 1 and 2 (Figure 2b).

It is interesting to note that the stock-recruit residuals for the last two years in the series (1998 and 1999) are negative (Figure 3).

Compared to previous results, both models indicate a slightly better recent status for the resource, with a leveling out of an earlier decline in spawning biomass (Figures 7a and b), a consequence of recruitment above expected levels in the mid-1990s (Figure 3). Differences nevertheless are relatively small and would not appear sufficient to warrant an "Exceptional Circumstances" override of OMP recommendations.

References

Glazer, J.P. 2009a. The separation of catch by area in the South Coast rock lobster fishery. MCM document, MCM/2009/JUL/SWG-SCRL/03.

Glazer, J.P. 2009b. A generalized linear model applied to the South Coast rock lobster CPUE data to obtain area-specific indices of abundance MCM document, MCM/2009/JUL/SWG-SCRL/02.

Glazer, J.P. 2009c. Size composition of male and female South Coast rock lobsters per season and area. MCM document, MCM/2009/JUL/SWG-SCRL/04.

Johnston, S.J. and D.S. Butterworth. 2008a. Near final specifications for the sex- and area-specific Operating models for testing OMPs for the South Coast rock lobster resource. MCM document, WG/08/08/SCRL17.

Johnston, S.J. and D.S. Butterworth. 2008b. Results for the final OMP 2008 for the South Coast rock lobster resource. MCM document, MCM/2008/AUG/SWG-SCRL/28.

MCM. 2007. Procedures for deviating from OMP output for the recommendation for a TAC, for initiating an OMP review. MCM document, reproduced as Appendix 2 of Rademeyer *et al.*, AFr. J. Mar. Sci. 2008 30(2):291-310.

Table 1: Annual catches (tons tail mass) per area in the South Coast rock lobster fishery (Glazer 2009a).

Year	Area 1	Area 2	Area 3
1973	No data available in the catch and effort database for these years.		
1974			
1975			
1976			
1977	245.68	254.76	166.56
1978	102.03	107.32	251.64
1979	31.89	29.92	60.19
1980	111.46	59.62	4.92
1981	138.26	169.32	40.42
1982	146.29	183.15	77.56
1983	125.16	280.90	117.94
1984	201.01	150.33	98.66
1985	85.52	200.30	164.17
1986	110.66	183.95	155.39
1987	106.23	146.37	199.40
1988	99.81	229.01	123.17
1989	112.36	241.00	98.64
1990	230.13	168.56	78.31
1991	183.06	204.02	137.46
1992	146.67	178.98	204.31
1993	191.22	242.92	90.13
1994	219.20	184.55	104.14
1995	122.68	249.99	132.23
1996	132.19	180.27	130.24
1997	105.57	156.72	154.10
1998	193.20	200.34	122.49
1999	248.62	157.99	105.55
2000	210.22	84.83	128.34
2001	108.53	111.05	68.41
2002	210.57	67.63	61.80
2003	207.18	123.88	18.94
2004	167.01	175.54	39.44
2005	173.67	134.14	74.19
2006	198.02	105.19	77.79
2007	173.43	101.76	111.81

Table 2: Standardized South Coast rock lobster CPUE (kg/trap) per area (Glazer 2009b).

Year	Area 1	Area 2	Area 3
1977	1.791	1.635	2.585
1978	1.335	1.541	1.940
1979	1.414	1.561	1.550
1980	2.082	1.742	1.256
1981	1.669	1.679	1.537
1982	1.443	1.373	1.437
1983	1.617	1.600	1.637
1984	1.577	1.554	1.506
1985	1.300	1.415	1.559
1986	1.469	1.484	2.439
1987	1.983	1.671	1.462
1988	1.888	1.823	1.748
1989	1.850	1.905	1.518
1990	1.643	1.433	1.278
1991	1.237	1.049	1.534
1992	1.079	1.210	1.401
1993	0.974	1.183	0.974
1994	0.999	0.964	1.056
1995	0.864	0.829	1.608
1996	0.793	0.742	0.934
1997	0.774	0.592	0.859
1998	1.176	0.555	0.636
1999	0.952	0.556	0.619
2000	1.169	0.561	0.698
2001	1.207	0.727	0.810
2002	1.369	0.688	0.648
2003	1.285	0.938	0.511
2004	1.242	1.147	1.200
2005	1.141	0.884	0.985
2006	0.865	0.721	0.760
2007	0.905	0.906	1.083

Table 3a: Proportional size distributions of male and female lobsters per year in Area 1 (Glazer 2009c).

Males

size	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
45	0.00065	0.00086	0	0.00057	0.00035	0	0	0	0	0	0	0	0.00032
50	0.00004	0.00723	0	0.00184	0	0.00033	0.00011	0.00008	0.00002	0	0.0002	0	0.00086
55	0.0011	0.01842	0.00176	0.0028	0.00105	0.00043	0.00041	0.00022	0.00026	0.00078	0.00761	0	0.00218
60	0.01046	0.02364	0.02567	0.02068	0.03155	0.00624	0.00401	0.00313	0.00612	0.00852	0.01742	0.00206	0.01943
65	0.06359	0.02964	0.05313	0.05872	0.12373	0.07068	0.03964	0.02766	0.03483	0.02857	0.02524	0.13866	0.0712
70	0.13023	0.07881	0.10201	0.09538	0.13074	0.14685	0.15205	0.11843	0.10852	0.09455	0.04388	0.2567	0.11546
75	0.08858	0.09376	0.13674	0.08918	0.07536	0.11952	0.16524	0.15936	0.1541	0.11452	0.07515	0.17938	0.10095
80	0.04532	0.07135	0.08485	0.06314	0.03715	0.06964	0.09662	0.11878	0.14115	0.10084	0.11382	0.22938	0.09136
85	0.02671	0.04958	0.0425	0.04063	0.01717	0.03908	0.04354	0.07858	0.08978	0.07319	0.09079	0.07113	0.05436
90	0.0184	0.02997	0.02267	0.02638	0.00841	0.02716	0.0212	0.04305	0.05088	0.05013	0.07417	0.01856	0.02142
95	0.01343	0.01819	0.01485	0.01756	0.00456	0.01299	0.00995	0.02329	0.02234	0.02693	0.02706	0.00361	0.00532
100	0.00594	0.0104	0.00986	0.01589	0.0014	0.00776	0.00624	0.00847	0.00869	0.01838	0.01203	0.00258	0.00309
105	0.00549	0.00239	0.00398	0.00777	0.0014	0.0038	0.00327	0.00459	0.00291	0.00998	0.002	0.00103	0.00069
110	0.00156	0.00123	0.00183	0.00246	0.00035	0.00161	0.00081	0.00158	0.00191	0.00427	0.0004	0	0.00023
115	0.00115	0.00007	0.00026	0.00096	0	0.00057	0.00043	0.00075	0.00038	0.00198	0.0006	0	0.00012
120	0.00005	0.00004	0.00044	0.00138	0	0.00028	0	0.0002	0.0002	0.0002	0.0004	0	0
125	0	0	0	0.00024	0	0	0	0.00014	0	0.00021	0	0	0.00005
Total	0.4127	0.43558	0.50055	0.44558	0.43322	0.50694	0.54352	0.58831	0.62209	0.53305	0.49077	0.90309	0.48704

Females

size	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
45	0	0.00168	0	0.00115	0	0	0	0	0	0	0	0	0.0006
50	0.00012	0.00939	0.00017	0.00241	0	0.00017	0	0.00008	0.00007	0	0.0008	0	0.00082
55	0.00094	0.02233	0.00604	0.00676	0.0028	0	0.0001	0	0.0004	0.00029	0.00741	0	0.00379
60	0.01801	0.02416	0.03646	0.02788	0.08587	0.02412	0.00902	0.00561	0.00542	0.0069	0.01482	0	0.03464
65	0.13857	0.06792	0.0701	0.09742	0.18647	0.13904	0.07412	0.04551	0.03244	0.03835	0.03707	0.000515	0.10727
70	0.19091	0.15445	0.13873	0.12882	0.16474	0.15633	0.16727	0.10005	0.085	0.09962	0.07436	0.001546	0.15164
75	0.119	0.12724	0.12677	0.10861	0.07781	0.08874	0.12588	0.10952	0.1095	0.10516	0.11984	0	0.11751
80	0.05444	0.07918	0.06858	0.0806	0.034	0.04492	0.04542	0.07095	0.08183	0.088	0.11404	0.005155	0.05843
85	0.03471	0.04399	0.02978	0.052	0.01122	0.02295	0.0213	0.04272	0.03756	0.05618	0.07656	0.001546	0.02374
90	0.0156	0.02196	0.01394	0.02135	0.0014	0.01073	0.00826	0.02318	0.01735	0.0374	0.03928	0.010825	0.01119
95	0.00869	0.00802	0.00492	0.01638	0.00105	0.0033	0.00367	0.00959	0.00566	0.01989	0.01462	0.052577	0.00232
100	0.00328	0.00295	0.00263	0.00382	0.00105	0.0018	0.00101	0.00285	0.00152	0.00929	0.00681	0.016495	0.00071
105	0.00274	0.00071	0.00113	0.0031	0.00035	0.00066	0.0002	0.00131	0.00039	0.00395	0.002	0.008247	0.0002
110	0.00023	0.00026	0.00009	0.00057	0	0.00019	0.0001	0.00029	0.00034	0.00133	0.0006	0	0.00008
115	0.00005	0.00011	0.00009	0.00184	0	0	0.0001	0.00007	0.00039	0.00055	0.0008	0	0
120	0	0.00007	0	0.00057	0	0.00009	0	0	0.00006	0.00004	0.0002	0	0.00004
125	0	0	0	0.00115	0	0	0	0	0	0	0	0	0
Total	0.58729	0.56442	0.49943	0.55443	0.56676	0.49304	0.45645	0.41173	0.37793	0.46695	0.50921	0.096906	0.51298

Table 3b: Proportional size distributions of male and female lobsters per year in Area 2 (Glazer 2009c).

Males

size	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
45	0	0.00005	0	0.00215		0	0	0	0	0.00021	0	0	0
50	0	0.00069	0.00032	0.00117		0	0.00012	0.00046	0.0001	0.00056	0.00004	0	0
55	0	0.01948	0.00452	0.00804		0	0.00168	0.00577	0.0002	0.00234	0.00046	0	0.00388
60	0.01377	0.08335	0.0455	0.04236		0.00643	0.01899	0.0206	0.0057	0.01831	0.00999	0.00299	0.04827
65	0.07153	0.11903	0.14714	0.08048		0.04033	0.05584	0.05781	0.04677	0.039	0.05388	0.09641	0.08977
70	0.09871	0.07983	0.17264	0.0799		0.14199	0.09462	0.09389	0.08398	0.07688	0.12666	0.21999	0.18374
75	0.08718	0.04667	0.09551	0.0401		0.09181	0.0946	0.09336	0.15241	0.08791	0.11724	0.20614	0.1247
80	0.07615	0.04316	0.0597	0.04941		0.07867	0.08828	0.07076	0.14525	0.0875	0.08696	0.19772	0.11418
85	0.05994	0.03307	0.02227	0.06053		0.05672	0.06045	0.04669	0.07431	0.05635	0.06053	0.03884	0.06841
90	0.03033	0.02536	0.00936	0.05555		0.07166	0.03887	0.03359	0.09616	0.039	0.03172	0.01086	0.02377
95	0.01702	0.01384	0.00323	0.04481		0.11123	0.02334	0.02087	0.03883	0.01864	0.01666	0.00326	0.01215
100	0.00432	0.01188	0.00097	0.02217		0.01347	0.01155	0.01494	0.01723	0.00922	0.00817	0.00081	0.00439
105	0.0036	0.00506	0.00097	0.01249		0.0067	0.00749	0.00916	0.00422	0.00354	0.0038	0.00081	0.00179
110	0.00024	0.00262	0	0.0036		0.00292	0.00365	0.00347	0.00287	0.00182	0.00229	0	0.00164
115	0.00141	0.00445	0	0.0037		0.00133	0.00217	0.00189	0.00126	0.00048	0.00095	0	0.00049
120	0.00129	0.00055	0	0.00005		0.00066	0.00068	0.00078	0.00021	0.0002	0.00047	0	0.00034
125	0.00135	0.00028	0	0.00042		0.0002	0.00035	0.00063	0.0001	0.00008	0.00006	0	0.00003
Total	0.46684	0.48937	0.56213	0.50693	0	0.62412	0.50268	0.47467	0.6696	0.44204	0.51988	0.77783	0.67755

Females

size	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
45	0	0.00002	0	0.00014		0	0.00006	0	0.00002	0.00018	0	0	0
50	0	0.00035	0.00032	0.0033		0	0.00021	0.00112	0.00003	0.00062	0.00003	0	0.00034
55	0.00054	0.03566	0.01065	0.00642		0.00013	0.00306	0.00579	0.00061	0.00332	0.00104	0	0.00154
60	0.02778	0.08641	0.08035	0.04306		0.00988	0.02573	0.02996	0.00809	0.01988	0.0179	0	0.02385
65	0.12164	0.13125	0.13875	0.07508		0.04391	0.06889	0.0711	0.03867	0.05352	0.079	0.002444	0.03722
70	0.11982	0.07579	0.11681	0.06868		0.0727	0.10037	0.10878	0.08374	0.10212	0.13615	0.005703	0.07449
75	0.09416	0.05969	0.05776	0.08274		0.079	0.10296	0.10421	0.08535	0.12662	0.12383	0.009777	0.06355
80	0.05404	0.04416	0.02097	0.07817		0.06156	0.08261	0.07894	0.05523	0.11367	0.06718	0.039109	0.05786
85	0.06611	0.03443	0.00678	0.05947		0.03642	0.05098	0.05212	0.02802	0.06853	0.02967	0.035035	0.03428
90	0.03033	0.02088	0.00323	0.04091		0.02381	0.02976	0.03365	0.01559	0.03966	0.01566	0.061651	0.01735
95	0.01267	0.01166	0.00129	0.02035		0.04128	0.01616	0.01994	0.0086	0.01892	0.00628	0.058121	0.00811
100	0.00459	0.00692	0.00097	0.00812		0.00537	0.00844	0.01141	0.00402	0.00706	0.00198	0.007876	0.00257
105	0.00135	0.00211	0	0.00302		0.00133	0.0046	0.00524	0.00161	0.00253	0.00088	0.002444	0.00076
110	0.00012	0.00067	0	0.00143		0.00027	0.00215	0.00198	0.00063	0.00109	0.00033	0	0.00036
115	0	0.00042	0	0.00165		0.0002	0.00094	0.00089	0.00013	0.0002	0.00013	0	0.00015
120	0	0.00012	0	0.00044		0	0.00032	0.00005	0.00007	0.00005	0.00003	0	0
125	0	0.00009	0	0.00008		0	0.00007	0.00017	0.00001	0.00001	0.00002	0	0
Total	0.53315	0.51063	0.43788	0.49306	0	0.37586	0.49731	0.52535	0.33042	0.55798	0.48011	0.22216	0.32243

Table 3c: Proportional size distributions of male and female lobsters per year in Area 3 (Glazer 2009c).

Males

size	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
45	0	0	0.00011	0.00415	0.00017	0.00018		0	0.0004	0	0	0	0
50	0.00118	0.00081	0.00043	0.02122	0.00169	0.00223		0.00319	0.00934	0.00036	0.001701	0.00013	0.00022
55	0.01747	0.00936	0.00524	0.04265	0.03317	0.01439		0.04238	0.0801	0.02762	0.009513	0.00063	0.00923
60	0.11158	0.06618	0.06636	0.09812	0.18514	0.08506		0.12721	0.16907	0.16853	0.050047	0.01675	0.10615
65	0.14543	0.09119	0.12844	0.11081	0.1865	0.13045		0.10734	0.11549	0.15071	0.071031	0.05625	0.1593
70	0.06933	0.06079	0.0679	0.07008	0.04908	0.08068		0.05877	0.04771	0.03931	0.046747	0.06538	0.07084
75	0.03372	0.05582	0.03959	0.03188	0.01523	0.03878		0.03928	0.02058	0.01404	0.038857	0.06163	0.02772
80	0.03573	0.06651	0.03804	0.02954	0.01472	0.03091		0.02513	0.0175	0.013	0.044327	0.08213	0.02566
85	0.02952	0.0568	0.0353	0.02639	0.0154	0.03065		0.03267	0.01669	0.01924	0.046793	0.09	0.02649
90	0.02462	0.04208	0.02965	0.02557	0.0088	0.02573		0.02779	0.01956	0.021218	0.049241	0.08325	0.02999
95	0.01962	0.03039	0.02447	0.01569	0.00406	0.01805		0.02473	0.01804	0.021224	0.042469	0.0525	0.02525
100	0.01294	0.01804	0.02138	0.01003	0.00152	0.01376		0.01053	0.00967	0.014928	0.0334	0.03125	0.02348
105	0.0067	0.00556	0.01118	0.00597	0.00068	0.00911		0.00559	0.00509	0.007017	0.020396	0.01063	0.01263
110	0.00254	0.00323	0.0067	0.00379	0.00068	0.00491		0.00339	0.00389	0.002795	0.00958	0.0075	0.00626
115	0.0022	0.00254	0.00423	0.0017	0.00017	0.0025		0.00126	0.0025	0.001118	0.003256	0.00163	0.00198
120	0.00313	0.0016	0.0026	0.00159	0	0.00089		0.00126	0.00105	0.000671	0.002402	0.00138	0.00084
125	0.00176	0.00218	0.00269	0.00143	0	0.00286		0.00257	0.00135	0.000363	0.002055	0.00025	0.00048
Total	0.51747	0.51308	0.48431	0.50061	0.51701	0.49114	0	0.51309	0.53803	0.502144	0.471815	0.56129	0.52652

Females

size	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
45	0.00012	0	0.00016	0.0104	0.00034	0.00009		0.0004	0	0.00003	0	0	0
50	0.00219	0.00169	0.00074	0.01596	0.00372	0.00366		0.00628	0.0111	0.00322	0.001231	0.000125	0.00029
55	0.02393	0.02097	0.01319	0.0525	0.06312	0.02475		0.05711	0.07954	0.05415	0.014842	0.000625	0.01458
60	0.13226	0.07818	0.08694	0.09977	0.19513	0.10373		0.12153	0.13371	0.16444	0.058556	0.014625	0.09887
65	0.12581	0.07964	0.10499	0.09488	0.11965	0.11624		0.08543	0.07435	0.09488	0.060458	0.034375	0.11744
70	0.04767	0.06244	0.06126	0.04997	0.03419	0.05799		0.03928	0.02622	0.05331	0.041858	0.0505	0.04765
75	0.02898	0.0601	0.05024	0.03887	0.01862	0.03833		0.0344	0.0173	0.0179	0.048994	0.051	0.03109
80	0.0284	0.05814	0.05465	0.0412	0.01794	0.04771		0.03107	0.0228	0.0196	0.060589	0.07575	0.02893
85	0.03247	0.04965	0.04896	0.03286	0.01422	0.03824		0.0381	0.02826	0.02982	0.074144	0.0765	0.03492
90	0.02876	0.03604	0.04286	0.02762	0.00914	0.03172		0.03695	0.02758	0.027038	0.07784	0.066625	0.04015
95	0.01443	0.01798	0.02489	0.01639	0.00355	0.02109		0.0177	0.01932	0.020223	0.048708	0.036875	0.03146
100	0.00748	0.00991	0.01265	0.00851	0.00169	0.01287		0.01096	0.01419	0.008079	0.02564	0.021125	0.01847
105	0.0035	0.00575	0.00531	0.00486	0.00102	0.00617		0.00271	0.0048	0.003299	0.009598	0.006	0.00667
110	0.00257	0.00391	0.00384	0.00348	0.00034	0.00241		0.00242	0.00189	0.00109	0.00259	0.002375	0.00212
115	0.00213	0.00293	0.00206	0.0014	0.00034	0.00152		0.00173	0.00045	0.000447	0.001859	0.001625	0.00055
120	0.00062	0.00059	0.00142	0.00043	0	0.00152		0.00029	0.00045	0.000252	0.000735	0.0005	0.00018
125	0.00122	0.00016	0.00038	0.00027	0	0.0008		0.00058	0	0.000084	0.000543	0.000125	0.00011
Total	0.48254	0.4869	0.51572	0.49937	0.48301	0.50884	0	0.48694	0.46196	0.497862	0.528185	0.43875	0.47348

Table 4: Model 3 (time varying selectivity MARAM method) estimated parameters and quantities of management interest. Biomass quantities are in MT.

Parameter/quantity	Global	Area 1	Area 2	Area 3
Total number of estimable parameters	220			
K^{sp} total female spawning biomass	792			
h S/R steepness parameter	0.804			
λ^A proportion R to Area A		0.40	0.42	0.18
μ^A rel. female scaling parameter for Area A		1.21	0.76	1.18
$l_{50}^{m,A}$ length at 50% selectivity for male lobsters in Area A (mm)		67.04	62.00	60.00
$l_{95}^{m,A}$ length at 95% selectivity for male lobsters in Area A (mm)		75.10	62.00	60.00
$l_{50}^{f,A}$ length at 50% selectivity for female lobsters in Area A (mm)		65.80	62.03	74.95
$l_{95}^{f,A}$ length at 95% selectivity for male lobsters in Area A (mm)		72.12	69.03	83.98
β^* growth function parameter	0.106			
$L_\infty^{m,A}$ L_∞ for male lobsters in Area A (mm)		104.04	106.69	113.07
$L_\infty^{f,A}$ L_∞ for female lobsters in Area A (mm)		101.03	100.49	110.14
κ growth curve parameter (yr^{-1})	0.088			
t_0 growth curve parameter (yr^{-1})	-1.95			
l_m^*	63.24			
l_f^*	63.13			
ϖ	7.03			
λ	0.73			
-ln L (CPUE)	-96.13	-39.67	-34.27	-22.18
CPUE σ		0.169	0.201	0.296
-ln L (CAL)	20.24	36.55	26.43	-42.56
CAL σ		0.090	0.110	0.071
SR residual penalty	5.89			
Time varying selectivity penalty	2.34			
Growth parameters penalty	2.54			
Time varying recruitment penalty	12.52			
Total –ln$L$ value	-52.04			
B_{06}^{sp} / K^{sp}	0.37			
B_{08}^{sp} / K^{sp}	0.37			
$B_{06}^{exp,A} / K_{1973}^{exp,A}$	0.30	0.31	0.32	0.28
$B_{06}^{exp,A}$	479	169	201	127
$B_{08}^{exp,A} / K_{1973}^{exp,A}$	0.30	0.32	0.31	0.27
$B_{08}^{exp,A}$	496	178	192	125

Table 5: Model 4 (time varying selectivity OLRAC method) estimated parameters and quantities of management interest. Biomass quantities are in MT.

Parameter/quantity	Global	Area 1	Area 2	Area 3
Total number of estimable parameters	346			
K^{sp} total female spawning biomass	1154			
h S/R steepness parameter	0.896			
λ^A proportion R to Area A		0.34	0.34	0.32
μ^A rel. female scaling parameter for Area A		1.11	0.96	1.29
$l_{50}^{m,A}$ length at 50% selectivity for male lobsters in Area A (mm)		66.48	63.57	52.94
$l_{95}^{m,A}$ length at 95% selectivity for male lobsters in Area A (mm)		74.40	70.34	69.34
$l_{50}^{f,A}$ length at 50% selectivity for female lobsters in Area A (mm)		65.10	61.49	57.82
$l_{95}^{f,A}$ length at 95% selectivity for male lobsters in Area A (mm)		70.97	68.49	79.21
β^* growth function parameter	0.121			
$L_\infty^{m,A}$ L_∞ for male lobsters in Area A (mm)		104.19	106.13	110.22
$L_\infty^{f,A}$ L_∞ for female lobsters in Area A (mm)		99.34	100.32	107.63
κ growth curve parameter (yr^{-1})	0.082			
t_0 growth curve parameter (yr^{-1})	-1.97			
l_m^*	64.19			
l_f^*	62.61			
ϖ	6.10			
λ	0.847			
-ln L (CPUE)	-97.04	-41.63	-37.56	-17.83
CPUE σ		0.158	0.180	0.341
-ln L (CAL)	-100.40	29.62	-2.13	-127.89
CAL σ		0.088	0.098	0.054
SR residual penalty	5.40			
Time varying selectivity penalty	7.84			
Growth parameters penalty	5.57			
Time varying recruitment penalty	11.29			
Total –ln$L$ value	-134.29			
B_{06}^{sp}/K^{sp}	0.50			
B_{08}^{sp}/K^{sp}	0.50			
$B_{06}^{exp,A}/K_{1973}^{exp,A}$	0.36	0.31	0.36	0.42
$B_{06}^{exp,A}$	540	167	211	162
$B_{08}^{exp,A}/K_{1973}^{exp,A}$	0.39	0.37	0.40	0.39
$B_{08}^{exp,A}$	582	200	233	150

Table 6a. Comparison of **Model 3** updated assessment results with those from previous assessment of Johnston and Butterworth (2009). The 2009 assessment values are in bold, with the 2008 assessment values in italics.

	Global	Area 1	Area 2	Area 3
B_{06}^{sp} / K^{sp}	**0.37** *0.34*			
$B_{06}^{\exp,A} / K_{1973}^{\exp,A}$	**0.30** *0.29*	**0.31** *0.33*	**0.32** *0.29*	**0.28** *0.26*
$B_{06}^{\exp,A}$	**497** *503*	**169** *177*	**201** *211*	**127** *115*

Table 6b. Comparison of **Model 4** updated assessment results with those from previous assessment of Johnston and Butterworth (2009). The 2009 assessment values are in bold, with the 2008 assessment values in italics.

	Global	Area 1	Area 2	Area 3
B_{06}^{sp} / K^{sp}	**0.50** *0.47*			
$B_{06}^{\exp,A} / K_{1973}^{\exp,A}$	**0.36** *0.37*	**0.31** *0.36*	**0.36** *0.34*	**0.42** *0.43*
$B_{06}^{\exp,A}$	**540** *584*	**167** *201*	**211** *222*	**162** *161*

Figure 1: Comparison of model fits to observed CPUE trends for Models 3 and 4.
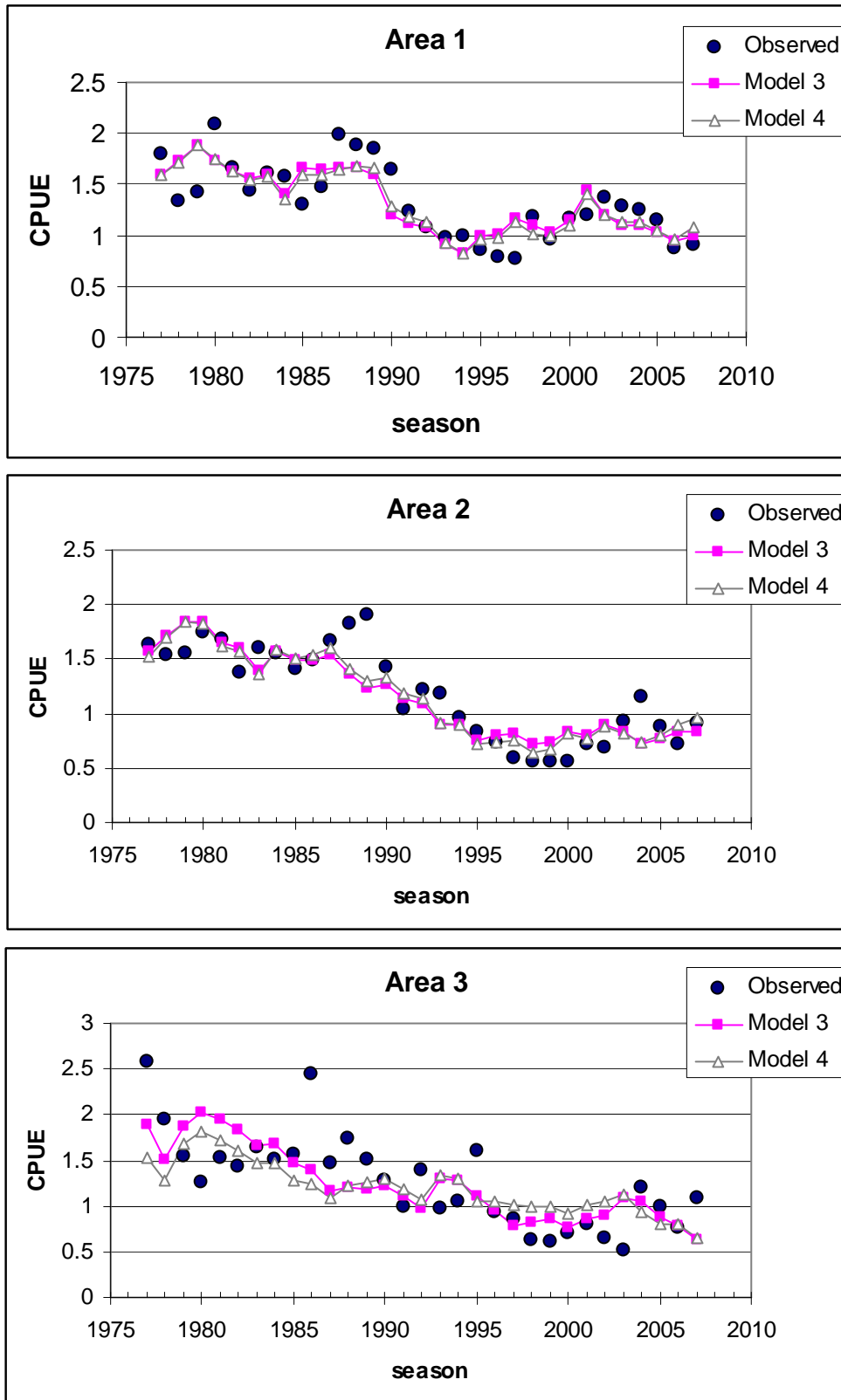
Figure 2a: Comparison of model fits to observed catch-at-length (CAL) trends for Models 3 and 4 averaged over all years. Note that proportions sum to 1 for males and females combined.
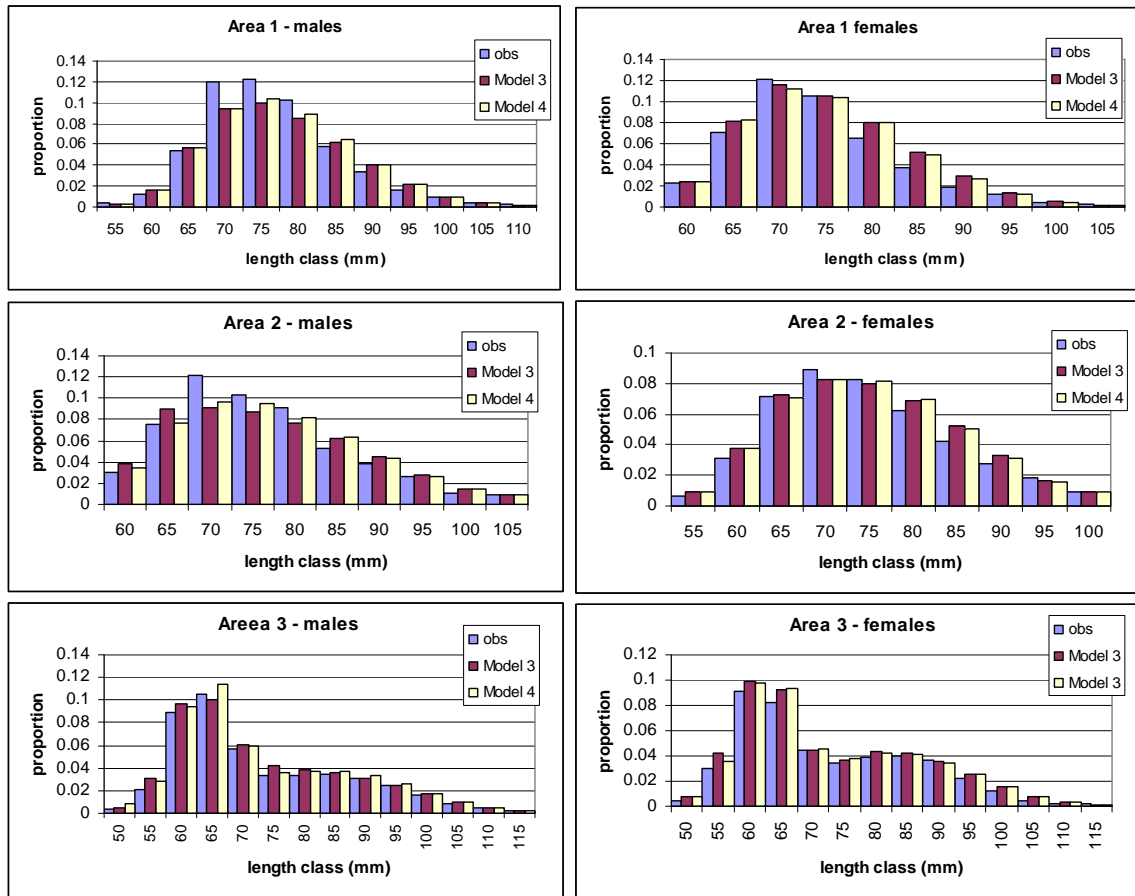
Figure 2b: Comparison of model fits to observed catch-at-length (CAL) trends for Models 3 and 4 for 2006 (a new year in the data period). Note that proportions sum to 1 for males and females combined.
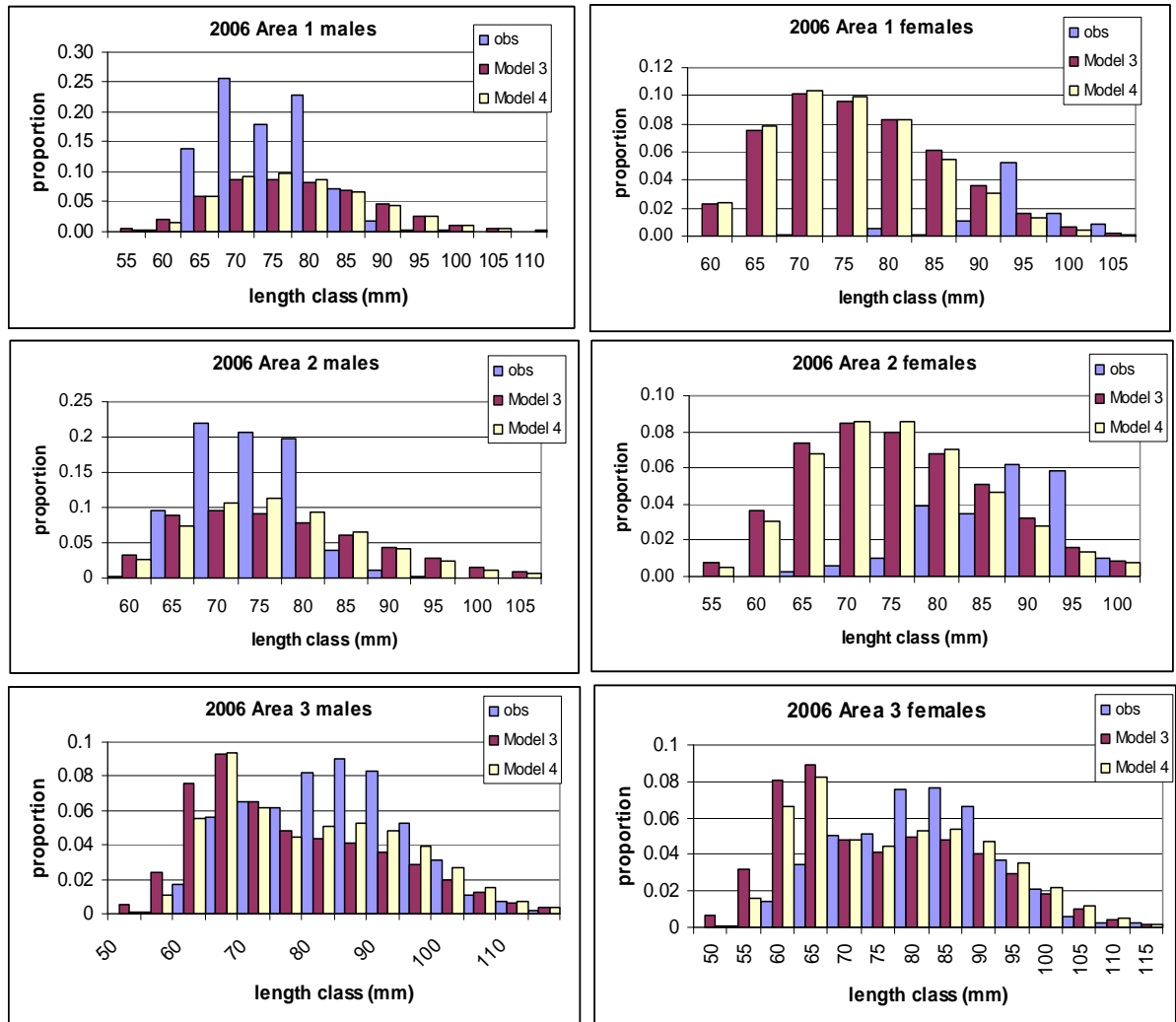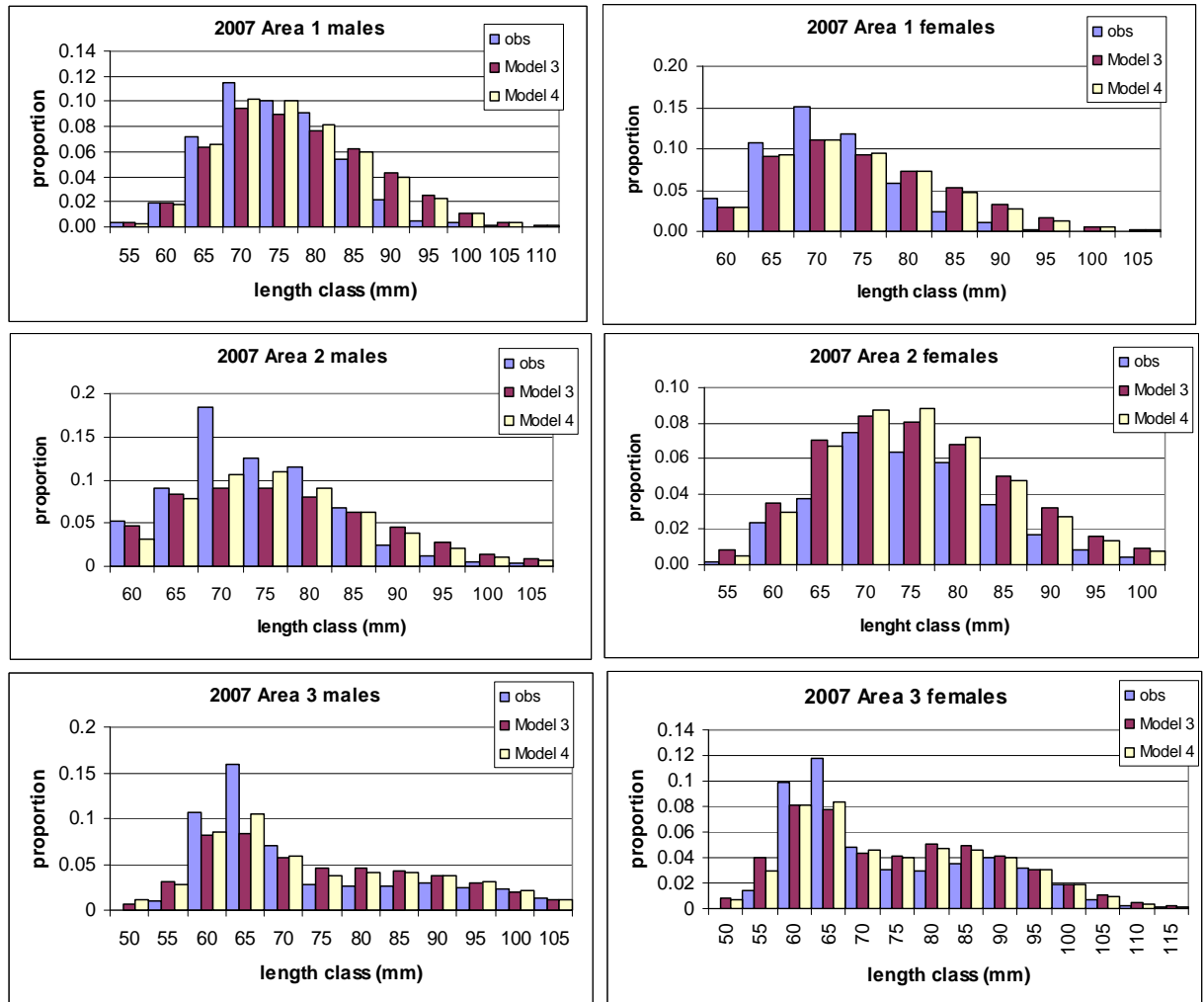
Figure 2c: Comparison of model fits to observed catch-at-length (CAL) trends for Models 3 and 4 for 2007 (the last year in the data period). Note that proportions sum to 1 for males and females combined.

Figure 3: Plots of the stock recruit residuals for Models 3 and 4.
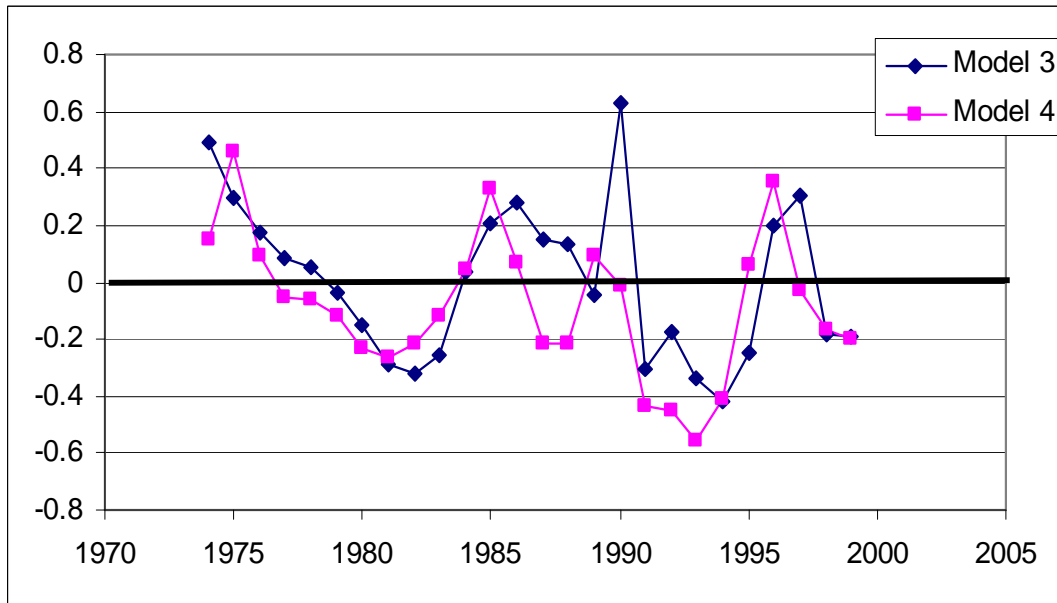
Figure 5: The MARAM method time-varying selectivity parameter $\delta_y^{m/f}$ values for each Area (and male and female) for Model 3.
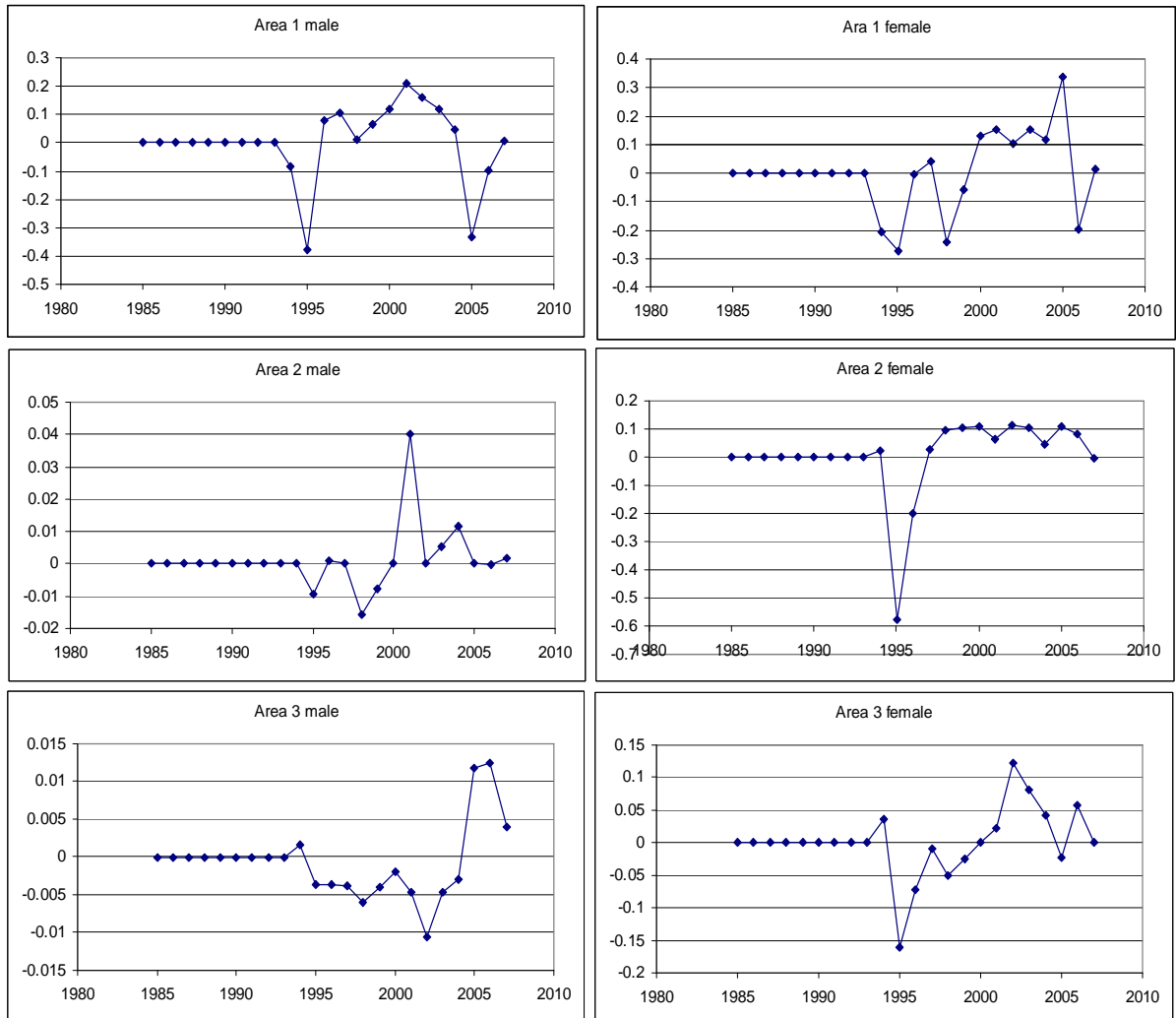
Figure 6: The OLRAC method time-varying selectivity parameter $x_y^{m/f}$ values for each Area (and male and female) for Model 4. The horizontal line shows the average value in each case.
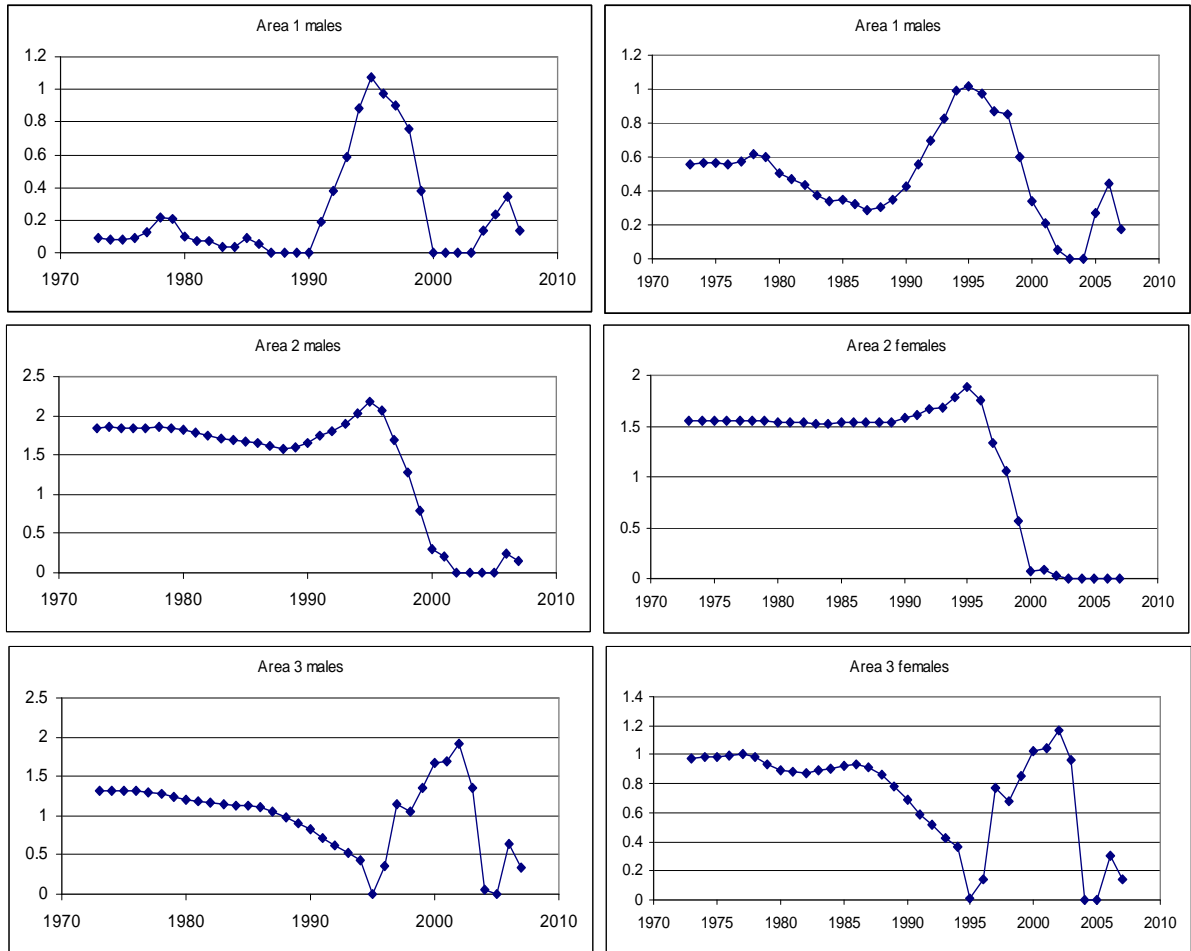
Figure 7a: Median annual B_{sp} trajectories (shown as squares) for the Reference Case Model 3 and the same model as fitted in 2008 (Johnston and Butterworth (2008b). The open circles show the 2009 updated assessment results, while the full squares show results from the 2008 assessment together with the OMP projection shown as a dashed line.
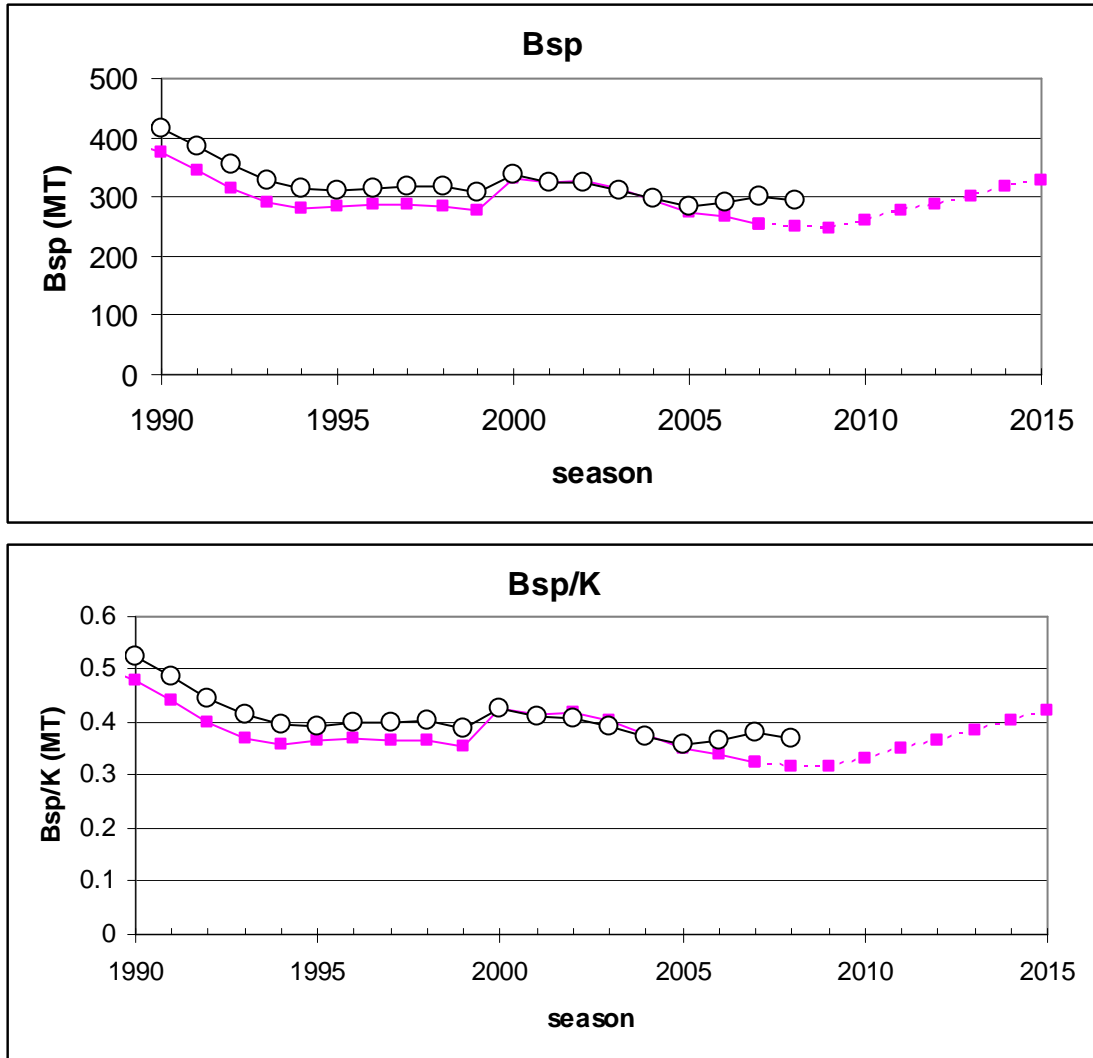
Figure 7b: Median annual B_{sp} trajectories (shown as squares) for the Reference Case Model 4 and the same model as fitted in 2008 (Johnston and Butterworth (2008b). The open circles show the 2009 updated assessment results, while the full squares show results from the 2008 assessment together with the OMP projection shown as a dashed line.