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A Generalized Linear Model applied to the South Cost rock lobster CPUE data to obtain area-specific indices of abundance

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Introduction

Area-disaggregated assessments for South Coast rock lobster are currently being developed. An important input to these assessments is the catch per unit effort (CPUE) data. A Generalized Linear Model (GLM) has been applied to the data to obtain area-specific standardized indices of abundance for input to the assessment models.

The data

The CPUE data cover the period 1978[1] – 2006. Certain records have been excluded from the analyses (as agreed at various Task Group Meetings held in 2007). These are as follows:

- Data from companies other than the four major companies for years prior to and including 1997.
- Data pertaining to Hout Bay Fishing vessels over the period 1998–2001, since they are considered to be unreliable.
- Sets with zero effort.
- Sets with zero catch.
- One record with a CPUE value of > 9kg/trap (this was considered an outlier).

The fishing grounds have historically been separated into four areas. However, based on recent analyses conducted by Gaylard and Bergh (2007), these four areas have been revised to three (Figure 1). It is these revised areas upon which the analyses are based.

The GLM

The base case GLM applied to obtain area-specific indices of abundance is of the form:

$$\ell n(CPUE) = I + \alpha_y + \beta_{seas} + \gamma_{depth} + \eta_{soak} + \kappa_{vess} + \lambda_{grid} + \varpi_{echo} + \theta_{gps} + \varsigma_{line} + \tau(traps) + (y \times area) + \varepsilon$$

where I is the intercept,
y is the split-year fishing season effect (1978-2006),
seas is the season effect
season 1 = October – December
season 2 = January – March
season 3 = April – June
season 4 = July – September,

[1] The year 1978 refers to the 1977/78 fishing season

depth is the depth effect

d75 : depth < 100

d125 : 100 $\leq$ depth < 150

d175 : 150 $\leq$ depth < 200

d225 : 200 $\leq$ depth < 250

d275 : depth $\geq$250,

soak is the soak time effect

soak1 : soak $\leq$ 24 hours

soak2 : 24 < soak $\leq$ 48

soak3 : 48 < soak $\leq$ 72

soak4 : 72 < soak $\leq$ 96

soak5 : soak > 96 hours,

vess is the vessel effect (42 vessels),

grid is the grid effect (290 grid squares),

echo is the echo-sounder effect,

gps is the GPS effect,

video is the video plotter effect,

traps is related to effort and is treated as a continuous variable,

($y\times area$) is a fixed effect interaction term where *area* comprises each of the three areas defined by Gaylard and Bergh (2007), and

ε is assumed to be normally distributed.

Note that both grid and area cannot be included as main effects in the model because of confounding.

Results and sensitivity tests

34837 records were included in the analyses, and the amount of variation explained by the model was 26.5%. The standardized CPUE indices per area were calculated by applying the equation $CPUE_{y,a} = e^{(\alpha_y + (y\times area) + median(\lambda_{grid}))}$, where $median(\lambda_{grid})$ is the median value amongst those for the grids specific to each area. The resultant indices are shown in Table 1 and Figure 2. The model output is presented in Table 2, and Figure 3 plots the distribution of the studentized residuals, which indicate some degree of non-normality. (When time permits, alternative distributional assumptions will be considered in an attempt to remove this effect).

Sensitivity tests, particularly with respect to the inclusion of various other interaction terms were considered. These were as follows:

- S1: include a (*seas*×*area*) interaction term as a fixed effect
- S2: include a (*y*×*seas*) interaction term as a random effect
- S3: replace the grid main effect with an area effect and include/exclude a (*y*×*superarea*) interaction term as a random effect, where *superarea* is defined in Figure 1.

Sensitivity test S1 resulted in an R^2 of 27.0%, which is hardly an improvement on the amount of variation explained by the base case model. This interaction term was therefore not considered further.

Figures 4a-c indicate that the inclusion of the (y×*seas*) interaction term (sensitivity test S2) as a random effect does not change the trend in the standardized indices in any of the areas when compared to the base case.

In order to obtain area-specific standardized CPUE indices for sensitivity test S3, the equation $CPUE_{y,a} = e^{\alpha_y + \lambda_{area} + (y \times area)}$ was applied. The resulting trends are shown in Figures 5a-c. It is clear from these plots that the resulting indices do not differ substantially from those of the base case.

Reference

Gaylard, J.D. and M.O. Bergh. 2007. A clustering of South Coast rock lobster fishing grid blocks based on similarity of CPUE trend. 9pp. South Coast rock lobster task group document (May 2007).

Table 1: Standardized South Coast rock lobster CPUE (kg/trap) per area as obtained from the base case model.

year	Area 1	Area 2	Area 3
1978	1.957	1.782	2.830
1979	1.453	1.678	2.102
1980	1.529	1.703	1.691
1981	2.248	1.898	1.350
1982	1.812	1.832	1.670
1983	1.575	1.513	1.566
1984	1.767	1.753	1.793
1985	1.756	1.734	1.672
1986	1.440	1.595	1.737
1987	1.657	1.660	2.731
1988	2.232	1.882	1.650
1989	2.096	2.065	1.952
1990	2.047	2.139	1.693
1991	1.806	1.611	1.434
1992	1.398	1.158	1.720
1993	1.210	1.341	1.580
1994	1.101	1.301	1.091
1995	1.152	1.075	1.161
1996	0.983	0.919	1.739
1997	0.886	0.828	1.019
1998	0.851	0.669	0.945
1999	1.276	0.624	0.695
2000	1.071	0.621	0.671
2001	1.305	0.635	0.746
2002	1.362	0.797	0.859
2003	1.503	0.736	0.706
2004	1.384	1.035	0.560
2005	1.351	1.257	1.312
2006	1.280	0.946	1.066

Table 2: Parameter estimates and associated statistics obtained from the base base model.

	Parameter	Estimate		Error	t Value	Pr > |t|
	Intercept	-1.794162	B	0.6737	-2.66	0.0077
y	1978	0.976146	B	0.0766	12.74	<.0001
y	1979	0.678728	B	0.0707	9.59	<.0001
y	1980	0.461229	B	0.0779	5.92	<.0001
y	1981	0.236189	B	0.1387	1.7	0.0886
y	1982	0.448914	B	0.0767	5.85	<.0001
y	1983	0.384016	B	0.0705	5.45	<.0001
y	1984	0.519776	B	0.0694	7.49	<.0001
y	1985	0.449799	B	0.0861	5.22	<.0001
y	1986	0.487802	B	0.0791	6.16	<.0001
y	1987	0.940548	B	0.0930	10.11	<.0001
y	1988	0.436742	B	0.0839	5.21	<.0001
y	1989	0.604543	B	0.0800	7.55	<.0001
y	1990	0.462462	B	0.0815	5.68	<.0001
y	1991	0.296004	B	0.0805	3.68	0.0002
y	1992	0.478364	B	0.0625	7.66	<.0001
y	1993	0.393087	B	0.0556	7.07	<.0001
y	1994	0.02261	B	0.0661	0.34	0.7324
y	1995	0.08486	B	0.0637	1.33	0.1829
y	1996	0.489372	B	0.0611	8.01	<.0001
y	1997	-0.045491	B	0.0551	-0.83	0.4091
y	1998	-0.120905	B	0.0527	-2.29	0.0219
y	1999	-0.427618	B	0.0519	-8.24	<.0001
y	2000	-0.463786	B	0.0525	-8.83	<.0001
y	2001	-0.357073	B	0.0532	-6.71	<.0001
y	2002	-0.216302	B	0.0624	-3.47	0.0005
y	2003	-0.411765	B	0.0655	-6.28	<.0001
y	2004	-0.6434	B	0.0810	-7.94	<.0001
y	2005	0.207385	B	0.0764	2.71	0.0067
y	2006	0	B	.	.	.
seas	1	0.181214	B	0.0141	12.81	<.0001
seas	2	0.229451	B	0.0139	16.5	<.0001
seas	3	0.145532	B	0.0138	10.51	<.0001
seas	4	0	B	.	.	.
soak	24	-0.167249	B	0.0170	-9.86	<.0001
soak	48	-0.072701	B	0.0162	-4.48	<.0001
soak	72	-0.022858	B	0.0213	-1.07	0.2827
soak	96	0.055889	B	0.0274	2.04	0.0411
soak	100	0	B	.	.	.
d	75	0.179408	B	0.2609	0.69	0.4916
d	125	0.152027	B	0.2606	0.58	0.5597
d	175	0.183017	B	0.2611	0.7	0.4833
d	225	-0.583692	B	0.4968	-1.17	0.24
d	275	0	B	.	.	.
boat	C20	0.10805	B	0.1508	0.72	0.4735
boat	CTA00001	0.207774	B	0.1199	1.73	0.0831
boat	CTA00002	-0.400978	B	0.1212	-3.31	0.0009
boat	CTA00003	-0.743222	B	0.1191	-6.24	<.0001
boat	CTA00004	-0.012447	B	0.1224	-0.1	0.919
boat	CTA00005	-0.935255	B	0.3069	-3.05	0.0023
boat	CTA00006	-0.413407	B	0.1201	-3.44	0.0006
boat	CTA00008	-1.568327	B	0.3708	-4.23	<.0001
boat	CTA00032	0.059995	B	0.1144	0.52	0.6
boat	CTA00039	-0.326969	B	0.1183	-2.76	0.0057
boat	CTA00048	-0.562945	B	0.1314	-4.28	<.0001
boat	CTA00065	-1.718888	B	0.1863	-9.23	<.0001
boat	CTA00073	-0.394702	B	0.1155	-3.42	0.0006
boat	CTA00082	-0.347134	B	0.1150	-3.02	0.0025
boat	CTA00083	-0.477514	B	0.1167	-4.09	<.0001
boat	CTA00108	-0.519222	B	0.1204	-4.31	<.0001
boat	CTA00129	-0.258052	B	0.1148	-2.25	0.0246
boat	CTA00130	-0.264154	B	0.1157	-2.28	0.0225
boat	CTA00139	-0.321389	B	0.1151	-2.79	0.0052
boat	CTA00148	-0.692983	B	0.1310	-5.29	<.0001
boat	CTA00161	-0.442769	B	0.1165	-3.8	0.0001
boat	CTA00162	-0.398484	B	0.1149	-3.47	0.0005
boat	CTA00164	-0.440118	B	0.1161	-3.79	0.0002
boat	CTA00167	-0.360543	B	0.1159	-3.11	0.0019
boat	CTA00193	-0.179737	B	0.1504	-1.19	0.2322
boat	HTB00033	-0.802405	B	0.1216	-6.6	<.0001
boat	HTB00041	-0.540693	B	0.1287	-4.2	<.0001
boat	HTB00043	0.28952	B	0.3728	0.78	0.4374
boat	HTB00108	-0.009812	B	0.1177	-0.08	0.9336
boat	PEA00039	-0.187271	B	0.1332	-1.41	0.1598

	Parameter	Estimate		Error	t Value	Pr > |t|
boat	PEA00053	-0.213148	B	0.1197	-1.78	0.0749
boat	PEA00091	-0.528598	B	0.1157	-4.57	<.0001
boat	PEA00130	0.216543	B	0.1506	1.44	0.1505
boat	PEA00270	-0.572273	B	0.1165	-4.91	<.0001
boat	PEA00272	-0.363003	B	0.1150	-3.16	0.0016
boat	PEA00273	-0.518933	B	0.1156	-4.49	<.0001
boat	PEA00305	-0.217176	B	0.1172	-1.85	0.0638
boat	PQ134	0.119342	B	0.1155	1.03	0.3015
boat	PQ715	0.060258	B	0.1197	0.5	0.6147
boat	XXX00992	-0.493645	B	0.2162	-2.28	0.0224
boat	XXX00995	0.323611	B	0.1269	2.55	0.0108
boat	XXX00996	0	B	.	.	.
grid	29	-0.714985	B	0.7057	-1.01	0.311
grid	30	0.690049	B	0.6591	1.05	0.2951
grid	32	0.820451	B	0.6261	1.31	0.19
grid	33	0.619911	B	0.6409	0.97	0.3334
grid	34	0.436605	B	0.6201	0.7	0.4814
grid	35	0.576822	B	0.6232	0.93	0.3547
grid	37	0.307662	B	0.6133	0.5	0.6159
grid	38	0.5964	B	0.6222	0.96	0.3378
grid	39	0.330059	B	0.6246	0.53	0.5972
grid	40	0.4834	B	0.6131	0.79	0.4304
grid	41	0.271703	B	0.6253	0.43	0.6639
grid	42	0.200783	B	0.6185	0.32	0.7455
grid	43	0.512199	B	0.6131	0.84	0.4035
grid	44	0.282575	B	0.6124	0.46	0.6445
grid	45	0.495227	B	0.6378	0.78	0.4375
grid	46	0.341939	B	0.6132	0.56	0.5771
grid	47	0.2163	B	0.6174	0.35	0.7261
grid	48	-0.742026	B	0.6172	-1.2	0.2293
grid	49	0.412141	B	0.6117	0.67	0.5005
grid	50	0.477107	B	0.6118	0.78	0.4355
grid	51	-0.016463	B	0.6186	-0.03	0.9788
grid	52	0.473799	B	0.6189	0.77	0.4439
grid	53	-0.008704	B	0.6142	-0.01	0.9887
grid	54	0.45057	B	0.6130	0.74	0.4623
grid	55	0.453815	B	0.6477	0.7	0.4835
grid	56	0.246623	B	0.6150	0.4	0.6884
grid	57	0.607192	B	0.6120	0.99	0.3211
grid	58	0.420949	B	0.6147	0.68	0.4934
grid	59	0.730172	B	0.6153	1.19	0.2353
grid	60	0.23428	B	0.6141	0.38	0.7029
grid	61	0.70943	B	0.6123	1.16	0.2466
grid	63	0.115019	B	0.6122	0.19	0.851
grid	64	0.113334	B	0.6134	0.18	0.8534
grid	65	0.582186	B	0.6117	0.95	0.3413
grid	66	0.113542	B	0.6482	0.18	0.861
grid	67	-0.008423	B	0.6144	-0.01	0.9891
grid	68	0.205302	B	0.6122	0.34	0.7374
grid	69	0.664122	B	0.6123	1.08	0.2781
grid	70	0.300679	B	0.6237	0.48	0.6298
grid	71	0.281197	B	0.6148	0.46	0.6474
grid	72	0.151118	B	0.6110	0.25	0.8047
grid	73	0.218918	B	0.6112	0.36	0.7202
grid	74	0.338909	B	0.6113	0.55	0.5793
grid	75	0.121047	B	0.6322	0.19	0.8482
grid	76	0.054698	B	0.7044	0.08	0.9381
grid	77	0.186248	B	0.6111	0.3	0.7605
grid	78	0.254074	B	0.6109	0.42	0.6775
grid	79	0.271981	B	0.6114	0.44	0.6565
grid	80	-0.016688	B	0.6115	-0.03	0.9782
grid	81	0.096444	B	0.6110	0.16	0.8746
grid	82	0.186752	B	0.6116	0.31	0.7601
grid	83	0.130766	B	0.6120	0.21	0.8308
grid	84	0.087576	B	0.6109	0.14	0.886
grid	85	-0.099478	B	0.6121	-0.16	0.8709
grid	86	0.141657	B	0.6137	0.23	0.8175
grid	87	0.123711	B	0.6124	0.2	0.8399
grid	88	0.233725	B	0.6119	0.38	0.7025
grid	89	0.156811	B	0.6122	0.26	0.7978
grid	90	-0.075291	B	0.6144	-0.12	0.9025
grid	91	0.084894	B	0.6129	0.14	0.8898
grid	92	0.20009	B	0.6116	0.33	0.7435
grid	93	0.179266	B	0.6116	0.29	0.7694

	Parameter	Estimate		Error	t Value	Pr > |t|
grid	94	0.307552	B	0.6146	0.5	0.6168
grid	95	0.383842	B	0.6489	0.59	0.5542
grid	96	0.021451	B	0.6130	0.03	0.9721
grid	97	-0.006081	B	0.6116	-0.01	0.9921
grid	98	-0.088671	B	0.6135	-0.14	0.8851
grid	99	-0.024014	B	0.6119	-0.04	0.9687
grid	100	0.070278	B	0.6114	0.11	0.9085
grid	101	0.128479	B	0.6115	0.21	0.8336
grid	102	-0.160258	B	0.6186	-0.26	0.7956
grid	103	-0.035794	B	0.6129	-0.06	0.9534
grid	104	0.035862	B	0.6113	0.06	0.9532
grid	105	-0.071492	B	0.6112	-0.12	0.9069
grid	106	0.017795	B	0.6145	0.03	0.9769
grid	107	-0.012798	B	0.6285	-0.02	0.9838
grid	108	-0.023451	B	0.6123	-0.04	0.9695
grid	109	-0.027918	B	0.6120	-0.05	0.9636
grid	110	-0.098022	B	0.6112	-0.16	0.8726
grid	111	0.192919	B	0.6140	0.31	0.7534
grid	112	-0.077825	B	0.6155	-0.13	0.8994
grid	113	-0.071623	B	0.6129	-0.12	0.907
grid	114	-0.128241	B	0.6123	-0.21	0.8341
grid	115	-0.041936	B	0.6112	-0.07	0.9453
grid	116	0.01994	B	0.6136	0.03	0.9741
grid	117	-0.327376	B	0.6172	-0.53	0.5958
grid	118	-0.130344	B	0.6124	-0.21	0.8315
grid	119	-0.119219	B	0.6124	-0.19	0.8457
grid	120	-0.030801	B	0.6112	-0.05	0.9598
grid	121	-0.195306	B	0.6126	-0.32	0.7499
grid	122	0.180034	B	0.6437	0.28	0.7797
grid	123	-0.163234	B	0.6150	-0.27	0.7907
grid	124	-0.107705	B	0.6124	-0.18	0.8604
grid	125	-0.060004	B	0.6113	-0.1	0.9218
grid	126	-0.091547	B	0.6134	-0.15	0.8814
grid	127	-0.6328	B	0.6244	-1.01	0.3108
grid	128	-0.013826	B	0.6216	-0.02	0.9823
grid	129	-0.044912	B	0.6124	-0.07	0.9415
grid	130	-0.164937	B	0.6117	-0.27	0.7874
grid	131	0.020915	B	0.6126	0.03	0.9728
grid	132	0.840556	B	0.6212	1.35	0.1761
grid	133	0.010874	B	0.6357	0.02	0.9864
grid	134	-0.09395	B	0.6166	-0.15	0.8789
grid	135	0.033632	B	0.6127	0.05	0.9562
grid	136	-0.047856	B	0.6121	-0.08	0.9377
grid	137	-0.223701	B	0.6132	-0.36	0.7153
grid	138	0.054	B	0.6141	0.09	0.9299
grid	139	-0.072438	B	0.6322	-0.11	0.9088
grid	140	-0.096347	B	0.6129	-0.16	0.8751
grid	141	-0.274505	B	0.6154	-0.45	0.6555
grid	142	-0.112805	B	0.6129	-0.18	0.854
grid	143	-0.194159	B	0.6131	-0.32	0.7515
grid	144	0.094451	B	0.8622	0.11	0.9128
grid	145	0.243278	B	0.7052	0.34	0.7301
grid	146	0.052234	B	0.6140	0.09	0.9322
grid	147	-0.579207	B	0.6269	-0.92	0.3555
grid	148	-0.19632	B	0.6135	-0.32	0.749
grid	149	-0.317085	B	0.6143	-0.52	0.6058
grid	150	0.068069	B	0.6163	0.11	0.912
grid	151	0.198858	B	0.8612	0.23	0.8174
grid	152	-0.485731	B	0.6238	-0.78	0.4362
grid	153	0.144998	B	0.6147	0.24	0.8135
grid	154	-0.110281	B	0.6127	-0.18	0.8572
grid	155	-0.079632	B	0.6120	-0.13	0.8965
grid	156	-0.205288	B	0.6153	-0.33	0.7387
grid	157	0.100799	B	0.6356	0.16	0.874
grid	158	-0.336818	B	0.6139	-0.55	0.5832
grid	159	-0.309322	B	0.6204	-0.5	0.6181
grid	160	-0.195039	B	0.6191	-0.32	0.7527
grid	161	-0.180233	B	0.6132	-0.29	0.7688
grid	162	-0.407688	B	0.6823	-0.6	0.5502
grid	163	-0.114252	B	0.6380	-0.18	0.8579
grid	164	-0.199434	B	0.6190	-0.32	0.7473
grid	165	0.059991	B	0.6176	0.1	0.9226
grid	166	0.00488	B	0.6527	0.01	0.994
grid	167	-1.502308	B	0.6403	-2.35	0.019

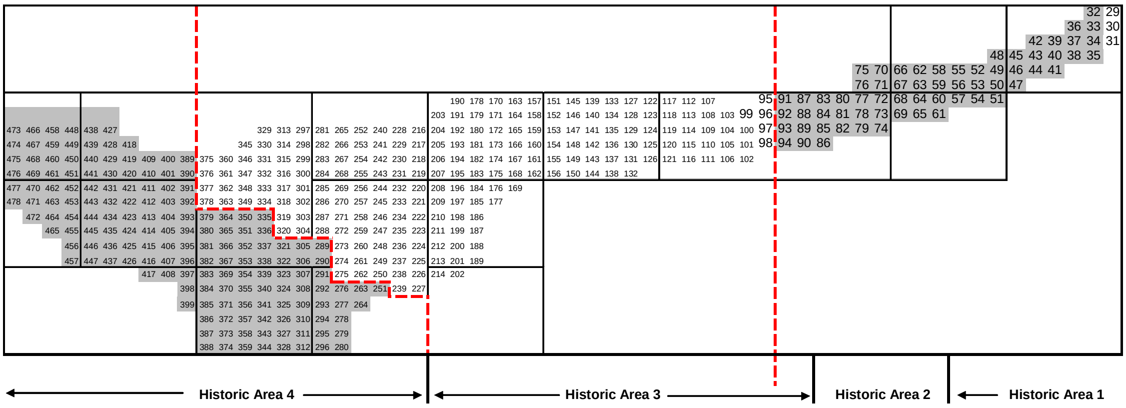
	Parameter	Estimate		Error	t Value	Pr > |t|
grid	168	0.481496	B	0.6232	0.77	0.4397
grid	169	0.746401	B	0.6458	1.16	0.2478
grid	170	-0.137529	B	0.6269	-0.22	0.8263
grid	171	-0.011429	B	0.6272	-0.02	0.9855
grid	172	-0.396628	B	0.7036	-0.56	0.573
grid	173	-0.290086	B	0.6413	-0.45	0.651
grid	174	0.26343	B	0.8619	0.31	0.7599
grid	175	-0.273633	B	0.7466	-0.37	0.714
grid	176	-2.342807	B	0.8612	-2.72	0.0065
grid	178	0.022583	B	0.6286	0.04	0.9713
grid	179	-0.285305	B	0.6183	-0.46	0.6445
grid	180	0.079147	B	0.7460	0.11	0.9155
grid	182	-0.022871	B	0.6596	-0.03	0.9723
grid	183	0.50239	B	0.6225	0.81	0.4196
grid	184	-0.228322	B	0.6412	-0.36	0.7218
grid	185	-0.470888	B	0.8609	-0.55	0.5844
grid	191	-0.111799	B	0.6692	-0.17	0.8673
grid	192	-0.535851	B	0.7044	-0.76	0.4469
grid	194	0.013545	B	0.6337	0.02	0.9829
grid	195	0.454034	B	0.6267	0.72	0.4688
grid	196	-0.098877	B	0.6440	-0.15	0.878
grid	197	-0.004967	B	0.6124	-0.01	0.9935
grid	198	-1.217122	B	0.8615	-1.41	0.1577
grid	202	-0.529087	B	0.8609	-0.61	0.5388
grid	206	0.335275	B	0.8603	0.39	0.6967
grid	208	-0.231883	B	0.8619	-0.27	0.7879
grid	209	0.463106	B	0.7466	0.62	0.5351
grid	210	0.079326	B	0.6402	0.12	0.9014
grid	220	-0.64137	B	0.6595	-0.97	0.3308
grid	226	-0.282253	B	0.8613	-0.33	0.7431
grid	227	0.301374	B	0.6688	0.45	0.6523
grid	229	-0.197918	B	0.8614	-0.23	0.8183
grid	233	-3.146698	B	0.8615	-3.65	0.0003
grid	237	-0.692095	B	0.8612	-0.8	0.4216
grid	238	-0.337241	B	0.7058	-0.48	0.6328
grid	239	-0.050302	B	0.7490	-0.07	0.9465
grid	246	0.246284	B	0.6703	0.37	0.7133
grid	247	-0.064781	B	0.7059	-0.09	0.9269
grid	250	-0.394636	B	0.7059	-0.56	0.5761
grid	251	0.12482	B	0.6582	0.19	0.8496
grid	254	0.423776	B	0.8607	0.49	0.6225
grid	256	0.035454	B	0.8613	0.04	0.9672
grid	262	-0.116797	B	0.7059	-0.17	0.8686
grid	263	0.468666	B	0.6438	0.73	0.4666
grid	273	-0.460886	B	0.6602	-0.7	0.4851
grid	274	-0.244898	B	0.6695	-0.37	0.7145
grid	275	-0.049243	B	0.7480	-0.07	0.9475
grid	277	-0.668094	B	0.8595	-0.78	0.437
grid	285	-0.046457	B	0.6346	-0.07	0.9416
grid	286	1.109941	B	0.7052	1.57	0.1155
grid	287	1.043181	B	0.6831	1.53	0.1267
grid	288	1.019758	B	0.8616	1.18	0.2366
grid	289	-0.595303	B	0.6235	-0.95	0.3397
grid	290	0.014738	B	0.6104	0.02	0.9807
grid	291	0.077003	B	0.6098	0.13	0.8995
grid	292	-0.035885	B	0.6317	-0.06	0.9547
grid	294	-0.100119	B	0.6432	-0.16	0.8763
grid	296	0.301606	B	0.6471	0.47	0.6412
grid	298	0.382432	B	0.6828	0.56	0.5754
grid	303	-0.037533	B	0.6439	-0.06	0.9535
grid	304	0.231013	B	0.6246	0.37	0.7115
grid	305	0.073804	B	0.6114	0.12	0.9039
grid	306	-0.042665	B	0.6096	-0.07	0.9442
grid	307	0.041299	B	0.6092	0.07	0.946
grid	308	0.177083	B	0.6097	0.29	0.7715
grid	309	0.179779	B	0.6099	0.29	0.7682
grid	310	0.399112	B	0.6150	0.65	0.5164
grid	311	-0.218803	B	0.7448	-0.29	0.7689
grid	313	0.14391	B	0.6531	0.22	0.8256
grid	315	0.432581	B	0.7055	0.61	0.5397
grid	317	0.246803	B	0.6262	0.39	0.6935
grid	318	0.056616	B	0.6476	0.09	0.9303
grid	319	-0.118814	B	0.6486	-0.18	0.8546
grid	320	0.078324	B	0.6214	0.13	0.8997

	Parameter	Estimate		Error	t Value	Pr > |t|
grid	321	0.091784	B	0.6177	0.15	0.8819
grid	322	-0.179055	B	0.6106	-0.29	0.7693
grid	323	0.031203	B	0.6090	0.05	0.9591
grid	324	0.092558	B	0.6098	0.15	0.8793
grid	325	0.242746	B	0.6094	0.4	0.6904
grid	326	0.219934	B	0.6379	0.34	0.7303
grid	327	0.142032	B	0.6131	0.23	0.8168
grid	328	0.476934	B	0.8613	0.55	0.5798
grid	329	-0.137873	B	0.6274	-0.22	0.8261
grid	334	0.337328	B	0.6190	0.54	0.5858
grid	335	0.040958	B	0.6152	0.07	0.9469
grid	336	0.07121	B	0.6112	0.12	0.9072
grid	337	-0.165876	B	0.6107	-0.27	0.7859
grid	338	-0.00566	B	0.6087	-0.01	0.9926
grid	339	0.177137	B	0.6088	0.29	0.7711
grid	340	0.103522	B	0.6090	0.17	0.865
grid	341	0.272347	B	0.6110	0.45	0.6558
grid	342	0.162757	B	0.6197	0.26	0.7928
grid	343	0.394587	B	0.6149	0.64	0.5211
grid	344	-0.152916	B	0.8594	-0.18	0.8588
grid	347	0.164592	B	0.8615	0.19	0.8485
grid	350	-0.315547	B	0.6505	-0.49	0.6276
grid	351	0.172664	B	0.6104	0.28	0.7773
grid	352	0.02466	B	0.6122	0.04	0.9679
grid	353	0.129555	B	0.6089	0.21	0.8315
grid	354	0.116698	B	0.6091	0.19	0.8481
grid	355	0.310699	B	0.6094	0.51	0.6102
grid	356	0.147406	B	0.6152	0.24	0.8106
grid	357	0.419466	B	0.6110	0.69	0.4924
grid	358	-0.248646	B	0.6499	-0.38	0.702
grid	359	0.564195	B	0.8605	0.66	0.512
grid	360	0.301257	B	0.6482	0.46	0.6421
grid	361	-0.709198	B	0.8614	-0.82	0.4103
grid	362	0.523453	B	0.8611	0.61	0.5433
grid	363	-0.197283	B	0.6285	-0.31	0.7536
grid	364	0.229887	B	0.6142	0.37	0.7082
grid	365	0.215602	B	0.6135	0.35	0.7252
grid	366	0.237148	B	0.6121	0.39	0.6984
grid	367	0.023797	B	0.6095	0.04	0.9689
grid	369	0.253151	B	0.6089	0.42	0.6776
grid	370	-0.052819	B	0.6111	-0.09	0.9311
grid	371	-0.108211	B	0.6228	-0.17	0.8621
grid	372	-1.125115	B	0.8578	-1.31	0.1896
grid	373	-0.207388	B	0.7453	-0.28	0.7808
grid	374	0.166927	B	0.6580	0.25	0.7997
grid	375	0.063977	B	0.8610	0.07	0.9408
grid	376	-0.338259	B	0.7043	-0.48	0.631
grid	377	-0.716703	B	0.7464	-0.96	0.337
grid	378	-0.627137	B	0.8617	-0.73	0.4667
grid	379	0.493475	B	0.6357	0.78	0.4376
grid	380	-0.151057	B	0.6176	-0.24	0.8068
grid	381	0.334762	B	0.6113	0.55	0.584
grid	382	-0.046782	B	0.6101	-0.08	0.9389
grid	383	0.090663	B	0.6098	0.15	0.8818
grid	384	-0.128868	B	0.6174	-0.21	0.8347
grid	386	0.064197	B	0.6600	0.1	0.9225
grid	388	-0.153071	B	0.8598	-0.18	0.8587
grid	391	-0.175488	B	0.6234	-0.28	0.7783
grid	393	0.269029	B	0.6341	0.42	0.6714
grid	394	-0.100708	B	0.6210	-0.16	0.8712
grid	395	-0.053703	B	0.6132	-0.09	0.9302
grid	396	-0.149719	B	0.6148	-0.24	0.8076
grid	397	-0.432762	B	0.6652	-0.65	0.5153
grid	398	0.11169	B	0.6329	0.18	0.8599
grid	399	-0.368334	B	0.6441	-0.57	0.5674
grid	403	-0.053183	B	0.6189	-0.09	0.9315
grid	405	0.091809	B	0.6133	0.15	0.881
grid	406	0.782651	B	0.7463	1.05	0.2943
grid	407	-0.227486	B	0.6684	-0.34	0.7336
grid	408	0.410193	B	0.6338	0.65	0.5175
grid	417	0.24493	B	0.6118	0.4	0.6889
grid	429	-0.757922	B	0.8613	-0.88	0.3789
grid	430	-2.73389	B	0.8597	-3.18	0.0015
grid	431	-0.164937	B	0.7026	-0.23	0.8144

Parameter			Estimate		Error	t Value	Pr > |t|
grid	434		1.638738	B	0.8608	1.9	0.057
grid	439		-1.581865	B	0.6671	-2.37	0.0177
grid	442		-0.324898	B	0.6159	-0.53	0.5978
grid	457		-0.038292	B	0.6779	-0.06	0.955
grid	466		-2.390388	B	0.7041	-3.4	0.0007
grid	478		0	B	.	.	.
echocode	0		-0.115367	B	0.0285	-4.05	<.0001
echocode	1		0	B	.	.	.
gpscode	0		0.024045	B	0.0418	0.57	0.5654
gpscode	1		0	B	.	.	.
linecode	0		-0.252502	B	0.0361	-7	<.0001
linecode	1		0	B	.	.	.
traps			-0.000133		0.0000	-15.9	<.0001
y*area	1978	1	-0.551401	B	0.0749	-7.36	<.0001
y*area	1978	2	-0.342986	B	0.0756	-4.54	<.0001
y*area	1978	3	0	B	.	.	.
y*area	1979	1	-0.55206	B	0.0695	-7.95	<.0001
y*area	1979	2	-0.105738	B	0.0712	-1.49	0.1374
y*area	1979	3	0	B	.	.	.
y*area	1980	1	-0.28342	B	0.0846	-3.35	0.0008
y*area	1980	2	0.126518	B	0.0874	1.45	0.148
y*area	1980	3	0	B	.	.	.
y*area	1981	1	0.327009	B	0.1374	2.38	0.0173
y*area	1981	2	0.459708	B	0.1395	3.29	0.001
y*area	1981	3	0	B	.	.	.
y*area	1982	1	-0.100888	B	0.0762	-1.32	0.1856
y*area	1982	2	0.211672	B	0.0769	2.75	0.0059
y*area	1982	3	0	B	.	.	.
y*area	1983	1	-0.176244	B	0.0701	-2.52	0.0119
y*area	1983	2	0.085037	B	0.0704	1.21	0.2274
y*area	1983	3	0	B	.	.	.
y*area	1984	1	-0.197388	B	0.0719	-2.74	0.0061
y*area	1984	2	0.096798	B	0.0680	1.42	0.1547
y*area	1984	3	0	B	.	.	.
y*area	1985	1	-0.133166	B	0.0924	-1.44	0.1494
y*area	1985	2	0.15597	B	0.0957	1.63	0.103
y*area	1985	3	0	B	.	.	.
y*area	1986	1	-0.369665	B	0.1002	-3.69	0.0002
y*area	1986	2	0.034449	B	0.0861	0.4	0.6892
y*area	1986	3	0	B	.	.	.
y*area	1987	1	-0.682425	B	0.1115	-6.12	<.0001
y*area	1987	2	-0.3785	B	0.1039	-3.64	0.0003
y*area	1987	3	0	B	.	.	.
y*area	1988	1	0.119652	B	0.1136	1.05	0.2922
y*area	1988	2	0.250801	B	0.1023	2.45	0.0142
y*area	1988	3	0	B	.	.	.
y*area	1989	1	-0.110925	B	0.0971	-1.14	0.2535
y*area	1989	2	0.175632	B	0.0892	1.97	0.0489
y*area	1989	3	0	B	.	.	.
y*area	1990	1	0.00749	B	0.0971	0.08	0.9385
y*area	1990	2	0.353098	B	0.0897	3.94	<.0001
y*area	1990	3	0	B	.	.	.
y*area	1991	1	0.048267	B	0.0937	0.52	0.6063
y*area	1991	2	0.235793	B	0.0950	2.48	0.0131
y*area	1991	3	0	B	.	.	.
y*area	1992	1	-0.389983	B	0.0709	-5.5	<.0001
y*area	1992	2	-0.276299	B	0.0726	-3.81	0.0001
y*area	1992	3	0	B	.	.	.
y*area	1993	1	-0.449051	B	0.0666	-6.74	<.0001
y*area	1993	2	-0.04415	B	0.0690	-0.64	0.5223
y*area	1993	3	0	B	.	.	.
y*area	1994	1	-0.173116	B	0.0745	-2.32	0.0201
y*area	1994	2	0.295825	B	0.0760	3.89	<.0001
y*area	1994	3	0	B	.	.	.
y*area	1995	1	-0.190138	B	0.0718	-2.65	0.0081
y*area	1995	2	0.042632	B	0.0755	0.56	0.5721
y*area	1995	3	0	B	.	.	.
y*area	1996	1	-0.753291	B	0.0712	-10.58	<.0001
y*area	1996	2	-0.518913	B	0.0713	-7.28	<.0001
y*area	1996	3	0	B	.	.	.
y*area	1997	1	-0.321635	B	0.0671	-4.8	<.0001
y*area	1997	2	-0.088348	B	0.0668	-1.32	0.186
y*area	1997	3	0	B	.	.	.
y*area	1998	1	-0.286677	B	0.0657	-4.37	<.0001

	Parameter		Estimate		Error	t Value	Pr > |t|
y*area	1998	2	-0.226421	B	0.0710	-3.19	0.0014
y*area	1998	3	0	B	.	.	.
y*area	1999	1	0.424862	B	0.0678	6.27	<.0001
y*area	1999	2	0.011736	B	0.0700	0.17	0.8669
y*area	1999	3	0	B	.	.	.
y*area	2000	1	0.285528	B	0.0633	4.51	<.0001
y*area	2000	2	0.043123	B	0.0723	0.6	0.5507
y*area	2000	3	0	B	.	.	.
y*area	2001	1	0.376676	B	0.0660	5.7	<.0001
y*area	2001	2	-0.042501	B	0.0760	-0.56	0.576
y*area	2001	3	0	B	.	.	.
y*area	2002	1	0.278772	B	0.0745	3.74	0.0002
y*area	2002	2	0.044251	B	0.0748	0.59	0.5541
y*area	2002	3	0	B	.	.	.
y*area	2003	1	0.572833	B	0.0743	7.71	<.0001
y*area	2003	2	0.159935	B	0.0805	1.99	0.0469
y*area	2003	3	0	B	.	.	.
y*area	2004	1	0.721722	B	0.0883	8.18	<.0001
y*area	2004	2	0.733401	B	0.0917	8	<.0001
y*area	2004	3	0	B	.	.	.
y*area	2005	1	-0.153424	B	0.0842	-1.82	0.0686
y*area	2005	2	0.076279	B	0.0860	0.89	0.3749
y*area	2005	3	0	B	.	.	.
y*area	2006	1	0	B	.	.	.
y*area	2006	2	0	B	.	.	.
y*area	2006	3	0	B	.	.	.

Figure 1: Historic and revised (dashed lines) area definitions of the South Coast rock lobster fishing grounds. The fishing grounds are further sub-divided into 21 super-areas as indicated by the smaller blocks below.



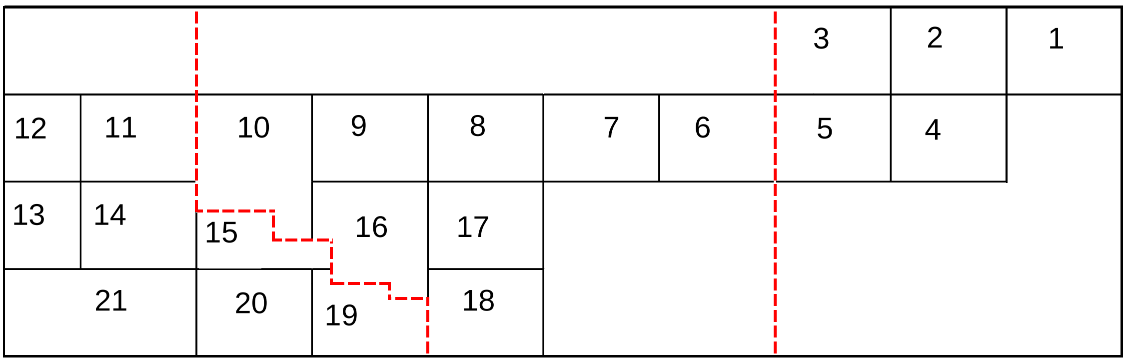


Figure 2: Standardized CPUE per area. The area-aggregated ("old") index that has been used in past assessments is shown for comparative purposes. Each index has been normalized to its mean.

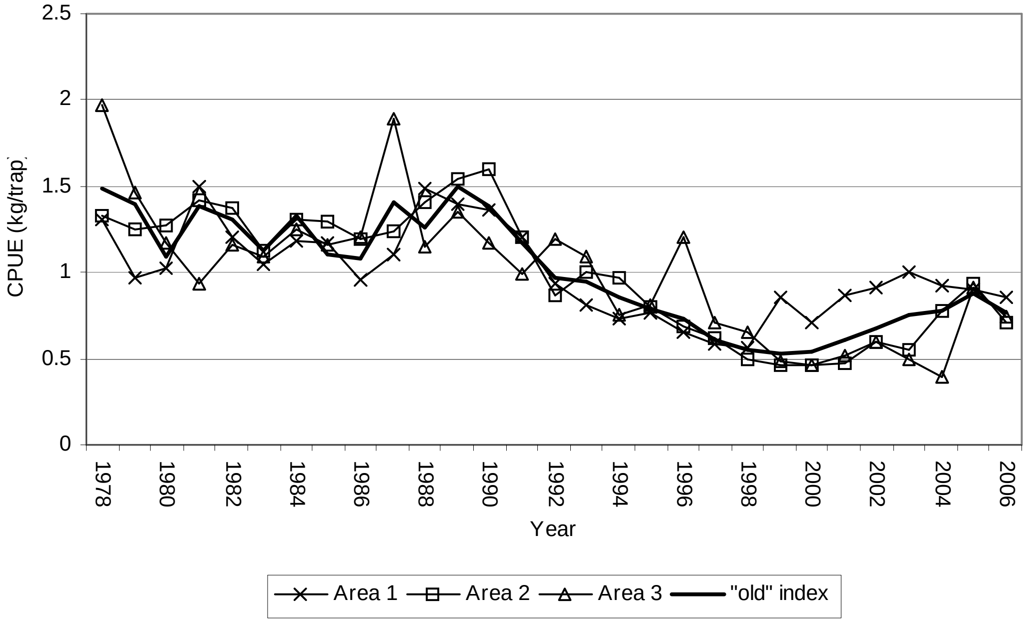


Figure 3: Distribution of studentized residuals obtained from the base case model.

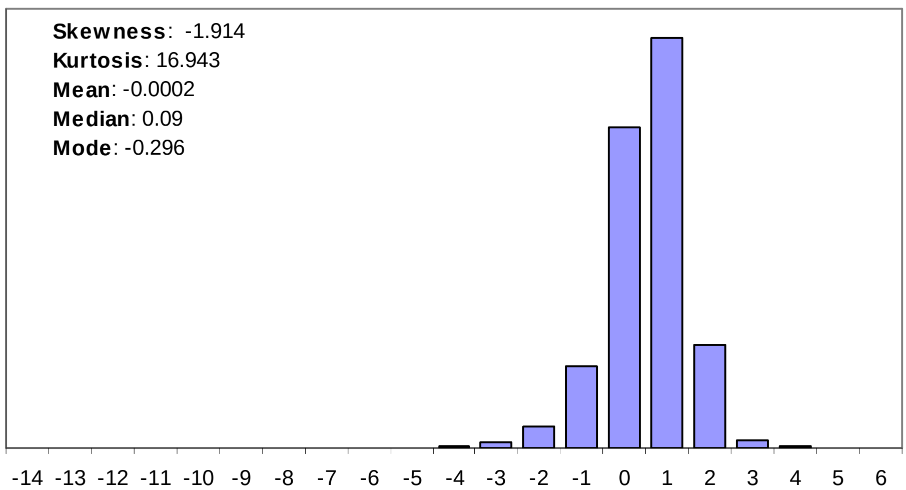
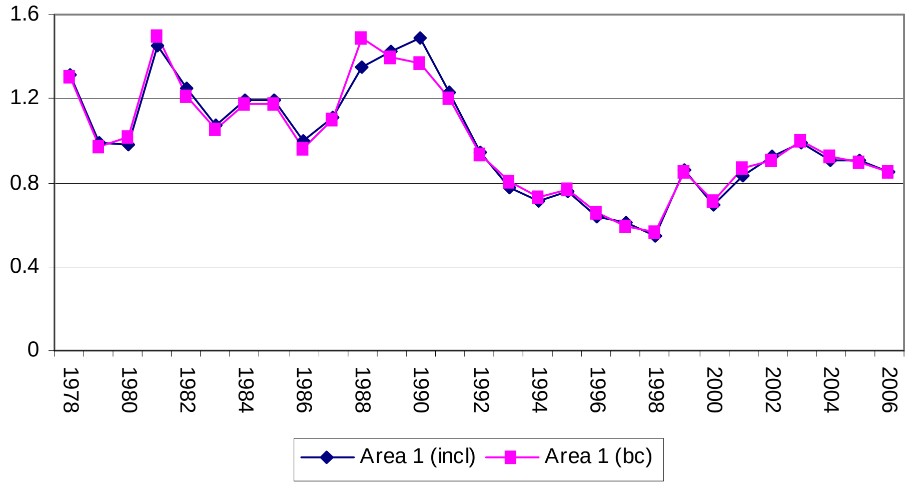
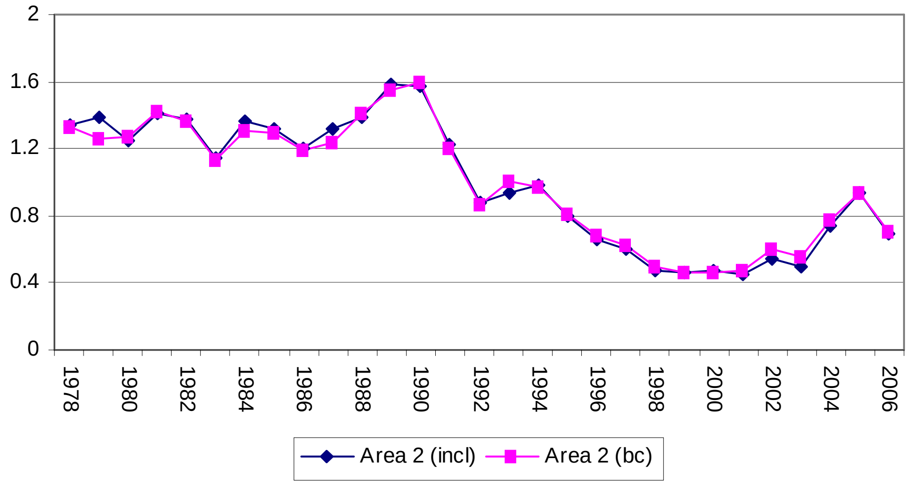


Figure 4a-c: Standardized CPUE per area, including (incl) and excluding (bc) a (*y*×*seas*) interaction term treated as a random effect. Each index has been normalized to its mean.

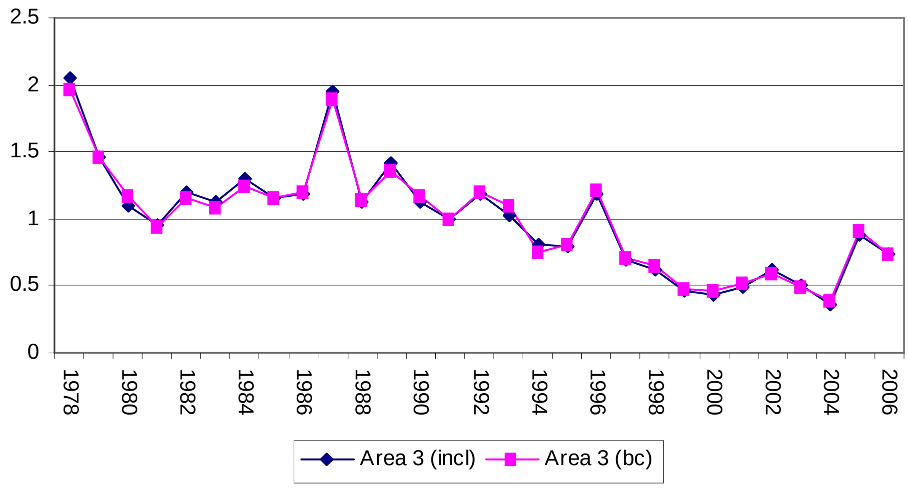
a)



b)

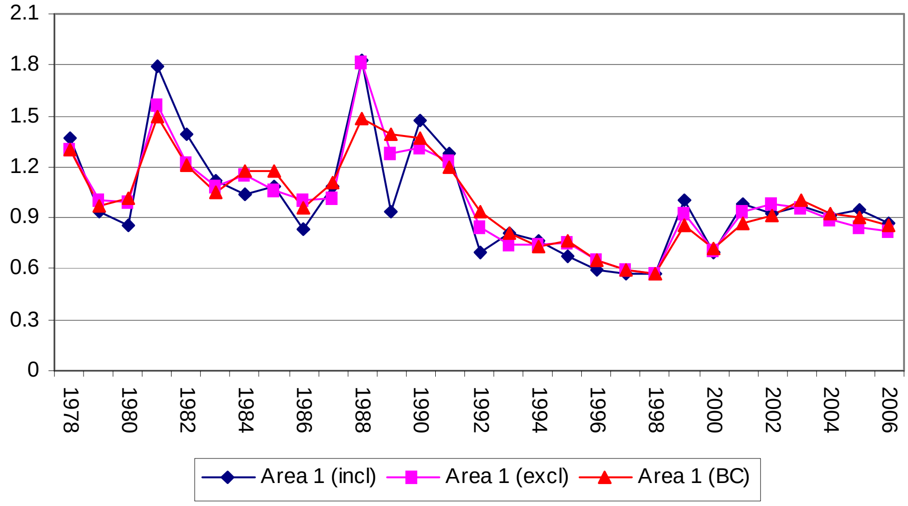


c)

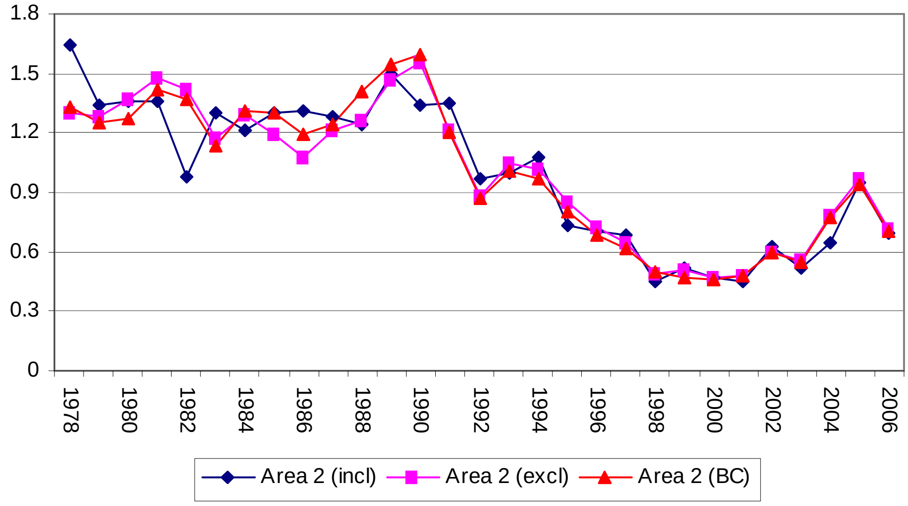


Figures 5a-c: Standardized CPUE per area, including (incl) and excluding (excl) a ($y \times superarea$) interaction term treated as a random effect. Also shown is the base case (BC) for comparative purposes. Each index has been normalized to its mean.

a)



b)



c)