Preliminary GLM standardisation of the commercial CPUE series for Abalone in Zones E and G from 1980 to 2007

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Introduction

The commercial CPUE series is considered during modeling of resource dynamics as an index of population abundance. However, a number of factors other than abundance may influence recorded values. Where sufficient data exists, General Linear Model (GLM) standardisation is able to take into account some of these effects, thereby producing a more reliable index.

Methods

Commercial Catch per Unit Effort (CPUE) data (including Limited Divers landings) from 1980 to 2007 was supplied by Angus Mackenzie (Marine and Coastal Management). Additional information that could potentially by used during standardisation included the area, date and diver number for each CPUE record. The date was considered in terms of the model year (running from October of the previous year until September of the current year) and four three month seasons. All independent variables, including season and model year, were considered as discrete factors when included in the model.

A total of 1031 CPUE records were available for Zone E and 1431 for Zone G. The data was first cleaned of likely errors by plotting the number of abalone landed against the recorded catch in kilograms, and removing outliers. In this way two likely errors were removed from the Zone E data but none from Zone G. An additional one record with no date from Zone E, five records from Zone G with no diver number and two records from Zone G with zero CPUE values were excluded from the analysis. A total of 1028 data points were therefore included in the analysis for Zone E and 1424 for Zone G.

Factors included in the model are considered to have a multiplicative effect

on CPUE. For this reason we use the natural logarithm of the CPUE ($lnCPUE$) during standardisation. We assume throughout that residual error is normally distributed. Taking the natural logarithm has the additional benefit of bringing the error distribution closer to this assumption.

Standardisation of the CPUE series involved fitting a number of nested models and the sequential removal of outliers (which may lead to a non-normal error distribution) and influential observations (which have a disproportionate impact on the estimated coefficients). Outliers were identified from the distribution of Studentised residuals and influential observations as those with high Leverage. Cook's statistic was also used to complement both these methods.

The following procedure was therefore adopted to GLM standardise the data:

1. Initial model fit including all factors, namely Area, Season, Model Year and Diver. There was not sufficient data to examine any interaction terms.
2. Preliminary removal of outliers and influential observations.
3. Re-fitting of the complete model.
4. Selection of the most appropriate model through removal of non-significant factors in a sequential (backwards) procedure.
5. Further removal of outliers and influential observations in an iterative process.

Results

Preliminary cleaning of the data after the initial fit of the complete model (with all factors included) removed 30 data points from Zone E and 23 from Zone G. In both cases subsequent fitting of the complete model showed that Season was not significant at the 5% level (with a p-value of 0.7182 for Zone E and 0.5588 for Zone G). This factor was therefore removed from the model. Re-fitting and a second round of cleaning removed a further four outliers and influential observations from Zone E and two from Zone G. This yielded a total of 994 data points for Zone E, and 1399 data points for Zone G. For both Zones the best fitting model (Model 1) can therefore be represented as:

$$lnCPUE = \mu + \alpha_{YEAR} + \beta_{AREA} + \gamma_{DIVER} + \varepsilon$$

where,

μ is the intercept term, and;

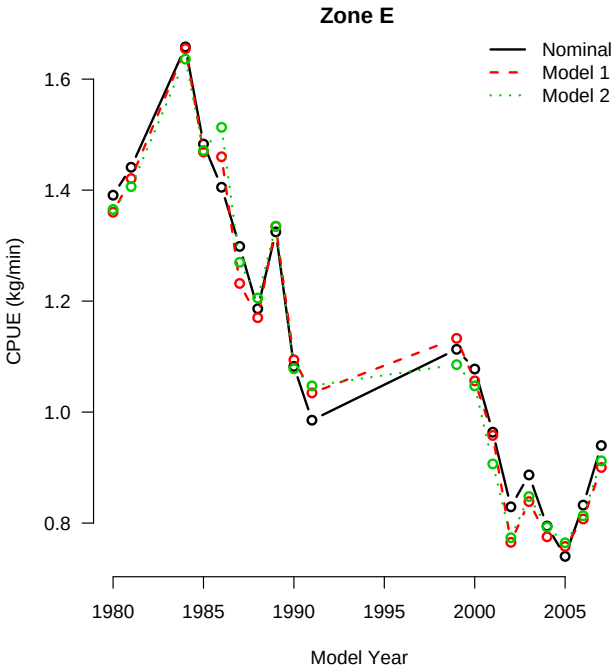

Figure 1: Nominal and standardised CPUE series plotted against Model Year: **Zone E**.

ε is the error, with $\varepsilon \sim N(0, \sigma^2)$.

R^2 values showed that approximately 68.1% and 60.5% of the variation was explained by the final model fit for Zones E and G respectively, with residual standard errors of 0.22 and 0.23. The nominal and standardised CPUE series are shown in Figures 1 and 2 and listed in Tables 1 and 2. Anova tables and estimated coefficients are given in the Appendix in Tables 3 and 4 for Zone E and Tables 5 and 6 for Zone G.

Secondary model fit

Although Diver makes a significant contribution to the model's explanatory power, Tables 4 and 6 show that a large number of the coefficients included in the model are not significant. We therefore re-fitted the model without the Diver factor included. The model for this secondary fit (Mode 2) was therefore:

$$lnCPUE = \mu + \alpha_{YEAR} + \beta_{AREA} + \varepsilon$$

R^2 values showed that approximately 53.3% and 40.1% of the variation was explained by Model 2 for Zones E and G respectively, with residual standard

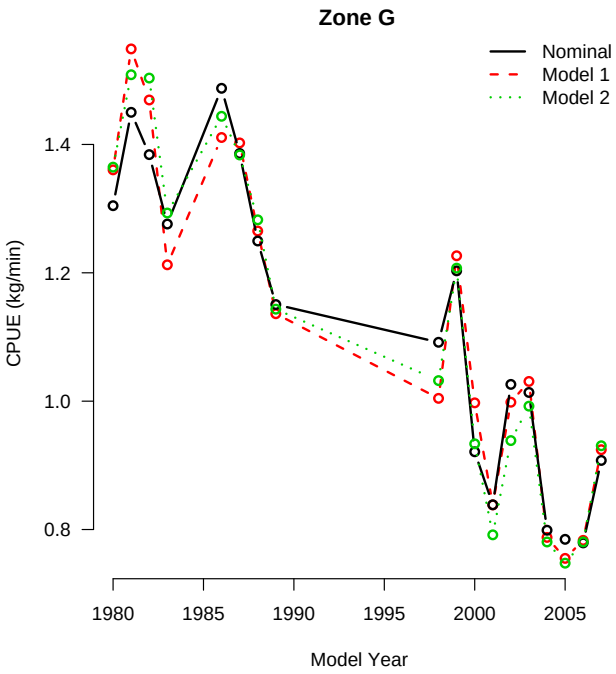

Figure 2: Nominal and standardised CPUE series plotted against Model Year: **Zone G**.

errors of 0.25 and 0.27. The Model 2 standardised CPUE series are shown in Figure 1 and 2 and listed in Tables 1 and 2. Anova tables and estimated coefficients are given in the Appendix in Tables 7 and 8 for Zone E and Tables 9 and 10 for Zone G. As expected the number of significant coefficients increased, although the improvement for Zone G was slight.

Conclusion

Standardisation of the commercial CPUE series provides a more reliable index of population abundance. Being the primary input into the stock assessment models used in Zones E and G makes this standardisation particularly important. The results presented here are however preliminary as further improvement to the model can likely be made. Notably the distribution of residuals for all the models reported here was heterodescastic, with increased variance at lower $lnCPUE$ values. Additional effort is therefore required to more closely approximate the model assumptions of homodeskasticity.

Table 1: Standardised commercial CPUE series: **Zone E**.

Model Year	n	Nominal	Model 1	Model 2
1980	19	1.39	1.36	1.37
1981	8	1.44	1.42	1.41
1982				
1983				
1984	6	1.66	1.65	1.64
1985	158	1.48	1.47	1.47
1986	9	1.41	1.46	1.51
1987	42	1.30	1.23	1.27
1988	16	1.19	1.17	1.21
1989	42	1.32	1.33	1.33
1990	19	1.08	1.09	1.08
1991	35	0.99	1.03	1.05
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999	24	1.11	1.13	1.09
2000	30	1.08	1.06	1.05
2001	24	0.96	0.96	0.91
2002	73	0.83	0.77	0.77
2003	43	0.89	0.84	0.85
2004	138	0.79	0.78	0.79
2005	127	0.74	0.76	0.76
2006	112	0.83	0.81	0.81
2007	69	0.94	0.90	0.91

Table 2: Standardised commercial CPUE series: **Zone G**.

Model Year	n	Nominal	Model 1	Model 2
1980	9	1.31	1.36	1.37
1981	10	1.45	1.55	1.51
1982	18	1.38	1.47	1.50
1983	8	1.28	1.21	1.29
1984				
1985				
1986	89	1.49	1.41	1.44
1987	76	1.39	1.40	1.38
1988	95	1.25	1.27	1.28
1989	98	1.15	1.14	1.14
1990				
1991				
1992				
1993				
1994				
1995				
1996				
1997				
1998	91	1.09	1.00	1.03
1999	17	1.20	1.23	1.21
2000	38	0.92	1.00	0.93
2001	95	0.84	0.84	0.79
2002	106	1.03	1.00	0.94
2003	116	1.01	1.03	0.99
2004	151	0.80	0.79	0.78
2005	173	0.79	0.76	0.75
2006	155	0.78	0.78	0.78
2007	54	0.91	0.92	0.93

Appendix

Table 3: Anova table for Model 1: **Zone E**.

	Df	Sum Sq	Mean Sq	F value	$Pr(>F)$
year	18	66.400	3.689	76.556	<0.00001
area	12	3.828	0.319	6.621	<0.00001
diver	91	19.586	0.215	4.467	<0.00001
Residuals	872	42.017	0.048		

Table 4: Estimated GLM coefficients for Model 1: **Zone E**.

Factor	Estimate	Std. error	t-value	$Pr(>\|t\|)$
Intercept	0.897	0.287	3.125	0.00183
year1981	0.083	0.121	0.684	0.49418
year1984	0.108	0.177	0.607	0.54382
year1985	-0.012	0.152	-0.078	0.93782
year1986	-0.018	0.171	-0.104	0.91703
year1987	-0.165	0.155	-1.068	0.28598
year1988	-0.170	0.162	-1.049	0.29446
year1989	-0.122	0.156	-0.781	0.43513
year1990	-0.320	0.161	-1.986	0.04732
year1991	-0.279	0.157	-1.774	0.07638
year1999	-0.116	0.145	-0.805	0.42108
year2000	-0.227	0.146	-1.554	0.12049
year2001	-0.322	0.153	-2.107	0.03540
year2002	-0.327	0.150	-2.176	0.02984
year2003	-0.296	0.154	-1.926	0.05447
year2004	-0.289	0.151	-1.906	0.05698
year2005	-0.311	0.152	-2.048	0.04089
year2006	-0.263	0.152	-1.731	0.08381
year2007	-0.142	0.153	-0.926	0.35476
areaCPMC	-0.698	0.181	-3.857	0.00012
areaCPPN	-0.733	0.174	-4.211	0.00003
areaGFKM	-0.693	0.176	-3.927	0.00009
areaHTB	-1.062	0.191	-5.546	<0.00001
areaKMMT	-0.931	0.182	-5.128	<0.00001
areaMLLP	-0.947	0.186	-5.102	<0.00001

areaOLFN	-0.798	0.208	-3.844	0.00013
areaPLTM	-0.641	0.185	-3.470	0.00055
areaSND	-0.896	0.250	-3.591	0.00035
areaSPNT	-0.813	0.180	-4.525	0.00001
areaSWRG	-0.691	0.177	-3.901	0.00010
areaWTS	-0.820	0.184	-4.454	0.00001
diver5	0.062	0.213	0.290	0.77222
diver7	0.272	0.169	1.611	0.10756
diver8	0.341	0.168	2.026	0.04307
diver10	0.441	0.187	2.366	0.01821
diver11	0.259	0.177	1.460	0.14472
diver12	0.051	0.270	0.189	0.84989
diver13	0.206	0.171	1.208	0.22724
diver14	0.191	0.176	1.086	0.27768
diver16	0.373	0.227	1.642	0.10103
diver17	0.045	0.221	0.205	0.83800
diver19	0.239	0.222	1.078	0.28144
diver22	0.120	0.167	0.721	0.47081
diver24	0.149	0.220	0.679	0.49760
diver25	0.058	0.193	0.300	0.76429
diver26	0.215	0.221	0.975	0.32970
diver29	0.076	0.168	0.452	0.65127
diver32	0.156	0.203	0.771	0.44113
diver34	0.204	0.174	1.168	0.24321
diver35	0.064	0.209	0.306	0.75945
diver36	0.285	0.204	1.396	0.16299
diver37	0.262	0.187	1.401	0.16142
diver40	0.103	0.173	0.597	0.55073
diver41	0.179	0.177	1.013	0.31127
diver43	0.098	0.178	0.552	0.58079
diver45	0.087	0.172	0.504	0.61414
diver46	0.144	0.232	0.619	0.53576
diver48	0.197	0.166	1.181	0.23781
diver49	0.198	0.172	1.151	0.25016
diver51	0.219	0.176	1.243	0.21421
diver55	0.348	0.174	1.994	0.04642
diver56	0.204	0.248	0.824	0.41006
diver57	0.046	0.247	0.187	0.85152

diver62	0.165	0.176	0.940	0.34754
diver64	0.057	0.202	0.281	0.77906
diver67	0.117	0.258	0.455	0.64931
diver81	-0.124	0.223	-0.558	0.57694
diver91	-0.361	0.256	-1.407	0.15975
diver103	0.020	0.204	0.100	0.92047
diver116	0.392	0.245	1.597	0.11056
diver121	-0.106	0.253	-0.418	0.67626
diver144	0.191	0.250	0.767	0.44348
diver161	-0.117	0.214	-0.549	0.58291
diver169	0.200	0.212	0.940	0.34735
diver174	0.115	0.196	0.588	0.55683
diver179	-0.035	0.213	-0.166	0.86829
diver196	-0.308	0.207	-1.486	0.13767
diver204	-0.121	0.225	-0.539	0.59002
diver207	0.172	0.235	0.733	0.46404
diver218	0.055	0.245	0.225	0.82222
diver223	0.237	0.262	0.906	0.36543
diver225	-0.030	0.245	-0.124	0.90168
diver226	-0.147	0.216	-0.681	0.49606
diver233	-0.107	0.220	-0.486	0.62702
diver239	-0.267	0.213	-1.256	0.20953
diver241	-0.304	0.222	-1.372	0.17035
diver245	-0.009	0.203	-0.046	0.96347
diver253	0.090	0.216	0.418	0.67609
diver351	-0.397	0.226	-1.758	0.07904
diver380	0.159	0.209	0.763	0.44577
diver381	-0.201	0.201	-0.999	0.31816
diver382	-0.138	0.208	-0.665	0.50621
diver383	-0.242	0.201	-1.201	0.22995
diver384	0.082	0.206	0.396	0.69195
diver385	-0.143	0.215	-0.665	0.50597
diver386	0.029	0.216	0.133	0.89393
diver387	-0.098	0.251	-0.392	0.69506
diver388	-0.030	0.217	-0.140	0.88850
diver389	-0.418	0.208	-2.013	0.04438
diver390	-0.218	0.206	-1.055	0.29159
diver391	-0.144	0.207	-0.697	0.48606

diver392	-0.061	0.220	-0.275	0.78317
diver394	-0.112	0.212	-0.531	0.59586
diver395	-0.130	0.203	-0.640	0.52216
diver396	-0.085	0.216	-0.393	0.69433
diver397	-0.218	0.208	-1.049	0.29452
diver398	0.209	0.207	1.010	0.31299
diver399	0.132	0.203	0.649	0.51650
diver400	-0.061	0.214	-0.284	0.77673
diver401	-0.109	0.208	-0.524	0.60044
diver402	-0.459	0.207	-2.211	0.02731
diver403	-0.421	0.216	-1.947	0.05186
diver404	0.048	0.225	0.211	0.83258
diver405	-0.341	0.203	-1.675	0.09421
diver406	-0.316	0.207	-1.529	0.12673
diver407	-0.168	0.204	-0.823	0.41074
diver408	-0.084	0.205	-0.409	0.68260
diver409	-0.113	0.206	-0.547	0.58482
diver418	-0.105	0.226	-0.467	0.64080
diver419	-0.015	0.268	-0.057	0.95452
diver420	-0.027	0.220	-0.122	0.90294
diver424	0.048	0.214	0.223	0.82360

Table 5: Anova table for Model 1: **Zone G**.

	Df	Sum Sq	Mean Sq	F value	$Pr(>F)$
year	17	67.766	3.986	72.651	<0.00001
area	15	1.974	0.132	2.399	0.00198
diver	127	34.203	0.269	4.908	<0.00001
Residuals	1239	67.982	0.055		

Table 6: Estimated GLM coefficients for Model 1: **Zone G**.

Factor	Estimate	Std. error	t-value	$Pr(>\|t\|)$
Intercept	0.361	0.244	1.480	0.13924
year1981	-0.004	0.150	-0.025	0.98026
year1982	0.113	0.135	0.837	0.40269
year1983	-0.071	0.160	-0.442	0.65872
year1986	-0.111	0.137	-0.810	0.41808
year1987	-0.117	0.137	-0.859	0.39044
year1988	-0.190	0.135	-1.409	0.15896
year1989	-0.249	0.135	-1.843	0.06564
year1998	-0.390	0.138	-2.821	0.00486
year1999	-0.308	0.155	-1.983	0.04764
year2000	-0.433	0.143	-3.019	0.00259
year2001	-0.618	0.143	-4.322	0.00002
year2002	-0.386	0.143	-2.696	0.00711
year2003	-0.356	0.144	-2.473	0.01352
year2004	-0.405	0.144	-2.808	0.00507
year2005	-0.447	0.144	-3.105	0.00195
year2006	-0.407	0.144	-2.823	0.00484
year2007	-0.306	0.146	-2.106	0.03541
areaBMPN	-0.068	0.125	-0.544	0.58640
areaDNGB	-0.261	0.075	-3.467	0.00055
areaDSSN	-0.069	0.062	-1.117	0.26416
areaGNZK	-0.050	0.066	-0.766	0.44359
areaGRTT	-0.030	0.165	-0.183	0.85502
areaHSBY	-0.156	0.118	-1.329	0.18425
areaHSPT	-0.038	0.154	-0.244	0.80725
areaICHB	0.164	0.155	1.054	0.29198
areaJCBS	-0.239	0.070	-3.404	0.00068

areaLRB	-0.153	0.149	-1.024	0.30623
areaMLKT	-0.019	0.064	-0.290	0.77160
areaMTRS	0.055	0.120	0.454	0.65026
areaSKLK	0.164	0.180	0.914	0.36095
areaSLDN	-0.053	0.079	-0.669	0.50386
areaYSTR	0.150	0.114	1.319	0.18725
diver2	-0.179	0.206	-0.868	0.38550
diver5	-0.020	0.218	-0.094	0.92520
diver6	-0.067	0.240	-0.278	0.78126
diver7	0.264	0.199	1.326	0.18502
diver8	0.220	0.203	1.085	0.27816
diver9	0.041	0.236	0.174	0.86205
diver10	-0.009	0.200	-0.047	0.96259
diver11	-0.353	0.204	-1.735	0.08295
diver13	0.164	0.198	0.826	0.40907
diver14	0.179	0.199	0.900	0.36843
diver16	0.092	0.244	0.377	0.70627
diver17	0.073	0.228	0.319	0.75012
diver18	-0.067	0.198	-0.336	0.73681
diver19	-0.155	0.239	-0.648	0.51737
diver20	-0.120	0.235	-0.513	0.60825
diver21	0.108	0.239	0.452	0.65126
diver22	0.192	0.202	0.949	0.34284
diver23	0.085	0.207	0.410	0.68158
diver24	0.084	0.210	0.400	0.68898
diver26	0.114	0.210	0.542	0.58801
diver28	-0.044	0.227	-0.194	0.84606
diver29	-0.019	0.202	-0.095	0.92454
diver32	0.065	0.212	0.305	0.76076
diver34	0.160	0.198	0.806	0.42017
diver35	0.186	0.201	0.929	0.35301
diver36	0.363	0.204	1.781	0.07508
diver37	0.224	0.215	1.042	0.29758
diver39	0.060	0.228	0.264	0.79167
diver40	-0.414	0.218	-1.898	0.05798
diver41	0.133	0.204	0.654	0.51341
diver42	0.025	0.232	0.108	0.91413
diver43	-0.126	0.192	-0.657	0.51142

diver45	0.101	0.202	0.503	0.61508
diver46	-0.061	0.288	-0.212	0.83244
diver48	0.099	0.198	0.501	0.61635
diver49	0.102	0.210	0.489	0.62495
diver51	0.209	0.206	1.018	0.30888
diver55	0.200	0.207	0.968	0.33338
diver57	0.016	0.272	0.058	0.95356
diver58	0.069	0.227	0.304	0.76100
diver59	0.303	0.218	1.387	0.16561
diver60	0.136	0.214	0.633	0.52658
diver62	0.058	0.197	0.296	0.76693
diver63	-0.273	0.240	-1.137	0.25557
diver64	0.041	0.203	0.203	0.83939
diver65	0.609	0.257	2.373	0.01778
diver70	-0.290	0.243	-1.194	0.23276
diver73	0.265	0.233	1.136	0.25627
diver74	0.321	0.257	1.248	0.21236
diver79	0.099	0.240	0.411	0.68125
diver80	0.147	0.202	0.724	0.46922
diver91	-0.185	0.212	-0.873	0.38308
diver93	0.044	0.208	0.211	0.83329
diver98	0.108	0.242	0.446	0.65560
diver101	0.188	0.244	0.773	0.43982
diver103	0.086	0.205	0.420	0.67424
diver116	0.152	0.233	0.650	0.51550
diver118	0.180	0.235	0.764	0.44482
diver124	0.176	0.262	0.670	0.50278
diver133	-0.014	0.211	-0.068	0.94616
diver145	0.054	0.211	0.256	0.79825
diver148	0.278	0.260	1.069	0.28519
diver160	0.006	0.217	0.029	0.97663
diver161	-0.162	0.219	-0.739	0.46032
diver162	0.299	0.213	1.403	0.16098
diver164	-0.296	0.212	-1.397	0.16279
diver167	0.204	0.242	0.843	0.39939
diver169	0.056	0.223	0.251	0.80156
diver174	0.150	0.203	0.739	0.46030
diver179	0.163	0.207	0.785	0.43239

diver182	-0.126	0.223	-0.567	0.57097
diver192	0.241	0.262	0.920	0.35766
diver196	-0.323	0.216	-1.493	0.13577
diver204	-0.118	0.223	-0.528	0.59729
diver207	-0.059	0.242	-0.244	0.80723
diver209	-0.421	0.208	-2.025	0.04312
diver213	0.136	0.209	0.649	0.51626
diver223	-0.129	0.260	-0.497	0.61945
diver226	0.034	0.202	0.169	0.86587
diver233	-0.273	0.208	-1.313	0.18936
diver235	0.176	0.262	0.673	0.50133
diver239	-0.353	0.211	-1.674	0.09432
diver241	-0.125	0.219	-0.571	0.56798
diver243	0.066	0.205	0.324	0.74618
diver244	0.029	0.244	0.118	0.90637
diver245	-0.145	0.205	-0.708	0.47936
diver253	-0.203	0.216	-0.940	0.34725
diver262	-0.368	0.235	-1.565	0.11775
diver351	-0.575	0.228	-2.525	0.01170
diver366	0.174	0.222	0.784	0.43294
diver367	-0.322	0.219	-1.472	0.14120
diver376	-0.092	0.262	-0.349	0.72732
diver380	-0.002	0.216	-0.010	0.99178
diver381	-0.310	0.218	-1.420	0.15592
diver382	-0.126	0.217	-0.583	0.56018
diver383	-0.447	0.210	-2.130	0.03341
diver384	-0.022	0.218	-0.100	0.92024
diver385	-0.111	0.220	-0.503	0.61505
diver386	-0.023	0.218	-0.107	0.91496
diver388	-0.195	0.223	-0.876	0.38146
diver389	-0.389	0.212	-1.833	0.06708
diver390	-0.298	0.214	-1.397	0.16274
diver391	-0.227	0.218	-1.043	0.29724
diver392	-0.274	0.218	-1.257	0.20892
diver393	-0.300	0.227	-1.318	0.18763
diver394	-0.298	0.215	-1.388	0.16554
diver395	-0.022	0.220	-0.099	0.92080
diver396	-0.148	0.216	-0.685	0.49318

diver397	-0.347	0.213	-1.631	0.10318
diver398	0.134	0.223	0.602	0.54744
diver399	0.111	0.215	0.515	0.60666
diver400	-0.257	0.218	-1.177	0.23944
diver401	-0.176	0.215	-0.818	0.41337
diver402	-0.303	0.220	-1.377	0.16879
diver403	-0.455	0.233	-1.951	0.05126
diver404	-0.101	0.243	-0.417	0.67665
diver405	-0.451	0.216	-2.086	0.03715
diver406	-0.510	0.216	-2.362	0.01835
diver407	-0.387	0.212	-1.831	0.06737
diver408	-0.072	0.220	-0.328	0.74319
diver409	-0.189	0.220	-0.857	0.39155
diver410	-0.062	0.213	-0.289	0.77299
diver411	-0.313	0.208	-1.502	0.13323
diver412	-0.190	0.219	-0.865	0.38716
diver418	-0.322	0.243	-1.323	0.18593
diver419	-0.117	0.227	-0.514	0.60759
diver424	-0.108	0.228	-0.473	0.63640

Table 7: Anova table for Model 2: **Zone E**.

	Df	Sum Sq	Mean Sq	F value	$Pr(>F)$
year	18	66.400	3.689	57.665	<0.00001
area	12	3.828	0.319	4.987	<0.00001
Residuals	963	61.604	0.064		

Table 8: Estimated GLM coefficients for Model 2: **Zone E**.

Factor	Estimate	Std. error	t-value	$Pr(>\|t\|)$
Intercept	0.992	0.195	5.090	<0.00001
year1981	0.030	0.113	0.264	0.79166
year1984	0.214	0.126	1.700	0.08938
year1985	0.048	0.068	0.706	0.48013
year1986	0.076	0.106	0.717	0.47338
year1987	-0.086	0.073	-1.170	0.24213
year1988	-0.124	0.088	-1.413	0.15807
year1989	-0.049	0.074	-0.670	0.50280
year1990	-0.236	0.084	-2.798	0.00525
year1991	-0.265	0.074	-3.604	0.00033
year1999	-0.196	0.086	-2.279	0.02288
year2000	-0.265	0.078	-3.419	0.00065
year2001	-0.409	0.081	-5.065	<0.00001
year2002	-0.568	0.068	-8.313	<0.00001
year2003	-0.476	0.072	-6.635	<0.00001
year2004	-0.543	0.065	-8.401	<0.00001
year2005	-0.580	0.065	-8.933	<0.00001
year2006	-0.518	0.065	-8.005	<0.00001
year2007	-0.403	0.068	-5.950	<0.00001
areaCPMC	-0.714	0.191	-3.732	0.00020
areaCPPN	-0.681	0.185	-3.674	0.00025
areaGFKM	-0.623	0.187	-3.331	0.00090
areaHTB	-0.973	0.201	-4.834	<0.00001
areaKMMT	-0.897	0.193	-4.655	<0.00001
areaMLLP	-0.843	0.196	-4.299	0.00002
areaOLFN	-0.746	0.221	-3.371	0.00078
areaPLTM	-0.654	0.193	-3.384	0.00074
areaSND	-0.750	0.226	-3.317	0.00095

areaSPNT	-0.705	0.188	-3.759	0.00018
areaSWRG	-0.654	0.187	-3.494	0.00050
areaWTS	-0.814	0.196	-4.150	0.00004

Table 9: Anova table for Model 2: **Zone G**.

	Df	Sum Sq	Mean Sq	F value	$Pr(>F)$
year	17	67.766	3.986	53.288	<0.00001
area	15	1.974	0.132	1.760	0.03531
Residuals	1366	102.185	0.075		

Table 10: Estimated GLM coefficients for Model 2: **Zone G**.

Factor	Estimate	Std. error	t-value	$Pr(>\|t\|)$
Intercept	0.453	0.112	4.037	0.00006
year1981	0.168	0.133	1.256	0.20920
year1982	0.097	0.113	0.859	0.39051
year1983	-0.054	0.134	-0.403	0.68717
year1986	0.056	0.096	0.590	0.55559
year1987	0.014	0.097	0.143	0.88624
year1988	-0.062	0.096	-0.646	0.51810
year1989	-0.177	0.096	-1.841	0.06577
year1998	-0.279	0.096	-2.899	0.00380
year1999	-0.123	0.113	-1.084	0.27848
year2000	-0.380	0.102	-3.732	0.00020
year2001	-0.544	0.097	-5.618	<0.00001
year2002	-0.307	0.099	-3.098	0.00199
year2003	-0.251	0.099	-2.539	0.01123
year2004	-0.491	0.097	-5.051	<0.00001
year2005	-0.535	0.097	-5.506	<0.00001
year2006	-0.491	0.097	-5.057	<0.00001
year2007	-0.316	0.102	-3.083	0.00209
areaBMPN	-0.132	0.125	-1.054	0.29203
areaDNGB	-0.204	0.079	-2.595	0.00955
areaDSSN	-0.143	0.066	-2.150	0.03171
areaGNZK	-0.185	0.070	-2.640	0.00838
areaGRTT	-0.137	0.182	-0.751	0.45282
areaHSBY	-0.299	0.122	-2.442	0.01473
areaHSPT	-0.103	0.174	-0.595	0.55168
areaICHB	0.096	0.172	0.557	0.57774
areaJCBS	-0.239	0.073	-3.272	0.00109
areaLRB	-0.199	0.169	-1.179	0.23845

areaMLKT	-0.210	0.067	-3.116	0.00187
areaMTRS	-0.241	0.132	-1.822	0.06861
areaSKLK	-0.137	0.203	-0.673	0.50107
areaSLDN	-0.081	0.081	-0.994	0.32036
areaYSTR	-0.174	0.082	-2.112	0.03490