Trends in policing effort and the number of confiscations for abalone

A. Brandão and D.S. Butterworth

Marine Resource Assessment & Management Group (MARAM)
Department of Mathematics and Applied Mathematics
University of Cape Town
Rondebosch 7701, Cape Town
August 2011

Summary

GLM methods are applied to compliance data on confiscations (and abandonments) and on policing effort to estimate recent trends in the amount of abalone that is poached. The results suggest that poaching has roughly doubled over the past two years.

Introduction

To obtain overall annual rates of increase in number of confiscations (which throughout this paper include abandonments) and in policing effort in a manner that takes into account possible monthly effects and, in the case of policing effort, the fact that various types of policing exercises are carried out, Generalised Linear Models (GLMs) are applied to these data, as summarised for the whole South Coast in Table 1a. The policing effort types listed there are as selected by scientists from the abalone working group as being those most likely to have resulted in abalone confiscations.

Methods

GLMs are used to investigate the variation of the number of confiscations of abalone as well as that of the policing effort that has occurred. Trends in the number of confiscations and in the policing effort are modelled in two ways: one by having the covariate "year" which is a factor which represents the year (i.e. a categorical nonlinear relationship is assumed between the number of confiscations/policing effort with the time period) and alternatively by having the covariate "Time" (essentially the date) which represents a continuous value for the year and month for which the data record applies (i.e. a linear relationship is assumed between the number of confiscations/policing effort with the date).

The expected policing effort (assuming a linear relationship with time) is modelled as:

$$\mathrm{E}(P) = \exp\left(\mu + \alpha_{month} + \beta_{type} + \gamma Time\right) \quad (1)$$

where

P is the policing effort, assumed to have an overdispersed Poisson distribution,
μ is the intercept,
α_{month} is the month effect,
β_{type} is the type of policing effect, where the "type" factor is associated with the different types of policing such as coastal patrols, permit checks, restaurant inspections, road blocks, sea patrols, slipway inspections and vessels inspections, and
Time is the time (date) representing the year and month to which the data applies, and γ is the associated coefficient.

When a nonlinear relationship is assumed between policing effort and time, the expected policing effort is modelled as:

$$\mathrm{E}(P) = \exp\left(\mu + \alpha_{month} + \beta_{type} + \delta_{year}\right) \quad (2)$$

where
δ_{year} is the year effect (2008 to 2011).

A weight is applied to each of the above GLMs to account for different levels of variance (beyond Poisson) in the data for the different measures of policing. The weight applied to the data is given by the inverse of the estimated overdispersion parameter obtained by fitting the GLM of Equation (1) (without the "type" factor) to each separate data set for the different types of policing employed.

The same procedure as for policing effort is applied to the number of confiscations. The one difference in the GLMs is that the β_{type} effect does not apply in this case. No weighting of the data is performed in this case.

Note that throughout "year" refers to Model-year, e.g. 2009 means the period October 2008 to September 2009.

Results

Table 2 shows the parameter estimates for the GLMs fitted to the policing effort data and to the number of confiscations.

For policing effort, whether a linear or nonlinear function is assumed over time, a positive trend is evident (Table 2 and Figure 1). An increase of 11% per year is obtained assuming a linear relationship. Under the categorical (nonlinear) approach, a steady increase remains apparent.

For the number of confiscations, an increasing trend (46% per year) is obtained if a linear relationship if assumed (Table 2). Under the categorical analysis, an increase is also evident (Table 2 and Figure 1), though note the large CI for 2011 for which only six months of data are available.

Thus, the instantaneous annual rates of increase obtained from the linear GLM are:

Confiscations: 46% (s.e. = 15.1%)

Policing effort: 11.3% (s.e. = 4.2%)

Together these suggest that removals from poaching have been increasing at an instantaneous rate of 34.7% p.a. (s.e.=15.7%) over the last three years. This corresponds to a net increase of 41.5% over one year, or 100% over two.

Maharaj (2011) applied simple log-linear regression analysis to the policing data, pooling the data on 3-monthly intervals. The instantaneous annual rate of increase obtained was 12.9% (s.e. = 4.3%), where the effort figure is an inverse variance weighted average over all of the indices which have been reported for all 12 quarters. Basing the analysis on only the five policing indices selected by the working group (as in the present analysis) and applying a simple log-linear regression analysis to the number of quarterly abalone confiscated, instantaneous annual rates of increase obtained are:

Confiscations: 40.7% (s.e. = 11.6%)
Policing effort: 11.8% (s.e. = 5.6%)

Together these suggest that removals from poaching have been increasing at an instantaneous rate of 28.9% p.a. (s.e.= 12.9%) over the last three years. This corresponds to a net increase of 33.5% over one year, or 78.2% over two. These results are very similar to those obtained by the GLM analysis above, with the latter suggesting slightly higher annual rate of increase in such removals.

Disaggregated by Region

The analyses pool data across all regions. Results might be biased if there has been a shift in policing effort allocation across regions over time. This has been addressed by disaggregating the data in Table 1a by regions (Zones A-D, Zones E-G and Kleinmond) as shown in Tables 1b-1d, and repeating the analyses above.

The results of these further GLMs are shown in Table 3-5 for Zones A-D, Zones E-G and Kleinmond respectively. Figure 1 shows the results for the categorical analysis for Zones A-D as well as for the "South Coast" as a whole (Cape Town to Arniston plus Saldanha Bay). The lowest row of plots in this Figure show the poaching level index as the ratio of the categorical factor estimates for confiscations and for effort each year, normalised as the average over the 2008 and 2009 years, together with the targeted decrease in poaching for 2010 and 2011 under the current abalone recovery plan. Figure 2 shows the similar plots for Zones E-G and for the Kleinmond region.

For Zones A-D there is an estimated decrease in effort over the last two years, in contrast to the estimated increase for the region as a whole. However in broad terms for both A-D and the region overall there is an estimated approximate doubling of poaching over the last two years. Results in Tables 4 and 5 and Figure 2 similarly indicate an increase in poaching in the Kleinmond area and more so in Zones E-G over the last two years.

Reference

Maharaj, G. 2011. Estimates of compliance policing effort. Fisheries/2011/Aug/SWG-AB/06.

Table 1a. Confiscations and policing effort on a monthly basis for the whole South Coast (Cape Town to Arnistion) and Saldanha Bay.

	Confiscations (# abalone)	Vehicles inspected	Slipway inspections	Coastal patrols	Road blocks	Sea patrols
April 08	609	564	501	739	17	2
May 08	2270	410	457	681	10	1
June 08	7901	374	348	598	2	1
July 08	751	428	384	634	3	0
Aug 08	21501	361	281	490	5	5
Sep 08	3279	236	137	159	3	0
Oct 08	13238	395	273	396	12	6
Nov 08	7095	390	163	160	10	2
Dec 08	7362	388	267	296	9	1
Jan 09	1184	758	285	378	12	8
Feb 09	13557	457	323	424	22	5
Mar 09	2434	445	250	279	35	5
April 09	9796	1284	409	332	30	2
May 09	3762	1086	331	364	38	11
June 09	3455	302	415	464	9	3
July 09	7049	207	632	762	2	0
Aug 09	12887	751	667	739	103	0
Sep 09	1601	214	322	417	7	8
Oct 09	10146	442	433	461	11	7
Nov 09	3807	834	380	632	13	4
Dec 09	12808	572	413	509	10	3
Jan 10	8731	1015	725	1039	13	3
Feb 10	4481	517	338	602	4	3
Mar 10	10726	352	581	571	7	1
Apr 10	4987	136	286	453	4	0
May 10	27509	404	268	380	11	0
Jun 10	8262	260	303	392	13	2
July 10	51406	934	564	551	17	0
Aug 10	15383	822	589	642	16	0
Sep 10	6304	192	233	339	3	5
Oct 10	14212	333	434	527	6	4
Nov 10	8187	765	417	536	19	6
Dec 10	11743	356	489	512	16	2
Jan 11	13855	396	680	1451	11	6
Feb 11	11986	137	591	514	6	13
Mar 11	13216	220	514	517	9	1

Table 1b. Confiscations and policing effort on a monthly basis for Zones A-D.

	Confiscations (# abalone)	Vehicles inspected	Slipway inspections	Coastal patrols	Road blocks	Sea patrols
April 08	336	359	278	566	10	0
May 08	2262	376	271	513	10	0
June 08	7649	325	207	460	2	0
July 08	498	367	218	463	2	0
Aug 08	21318	322	134	372	2	0
Sep 08	3279	214	87	112	3	0
Oct 08	13222	336	156	234	7	4
Nov 08	5780	255	97	92	4	1
Dec 08	7357	358	177	191	6	0
Jan 09	992	442	184	246	8	5
Feb 09	13353	277	163	255	9	3
Mar 09	275	387	136	168	34	4
April 09	9255	501	286	262	12	0
May 09	1964	282	194	239	15	1
June 09	3085	199	300	344	6	3
July 09	6463	167	496	550	0	0
Aug 09	12659	243	389	557	90	0
Sep 09	1486	129	159	257	1	8
Oct 09	7815	347	216	246	6	3
Nov 09	2714	338	167	416	6	2
Dec 09	12585	460	168	241	5	3
Jan 10	757	396	347	367	0	1
Feb 10	3920	500	168	242	4	3
Mar 10	10207	314	384	338	2	1
Apr 10	4173	95	128	236	0	0
May 10	26772	65	27	202	2	0
Jun 10	5968	106	157	214	7	2
July 10	13581	554	154	232	4	0
Aug 10	14836	160	152	235	3	0
Sep 10	6041	76	108	172	2	1
Oct 10	14141	126	138	219	1	2
Nov 10	7485	427	166	266	4	1
Dec 10	3040	196	171	235	2	2
Jan 11	13814	186	367	1186	2	3
Feb 11	5312	78	296	260	4	1
Mar 11	12400	59	135	243	3	0

Table 1c. Confiscations and policing effort on a monthly basis for Zones E-G.

	Confiscations (# abalone)	Vehicles inspected	Slipway inspections	Coastal patrols	Road blocks	Sea patrols
April 08	273	205	173	37	3	8
May 08	8	34	168	0	1	20
June 08	252	49	138	0	1	7
July 08	253	61	171	1	0	32
Aug 08	183	39	118	3	5	12
Sep 08	0	22	47	0	0	14
Oct 08	16	59	117	162	5	2
Nov 08	1315	135	66	68	6	1
Dec 08	5	30	90	105	3	1
Jan 09	192	316	101	132	4	3
Feb 09	204.1	180	160	169	13	2
Mar 09	2159	58	114	111	1	1
April 09	541	783	123	70	18	2
May 09	1798	804	137	125	23	10
June 09	370	103	115	120	3	0
July 09	586	40	136	212	2	0
Aug 09	228	508	278	182	13	0
Sep 09	115	85	163	160	6	0
Oct 09	2331	95	217	215	5	4
Nov 09	1093	496	213	216	7	2
Dec 09	223	112	245	268	5	0
Jan 10	7974	619	378	672	13	2
Feb 10	561	17	170	360	0	0
Mar 10	519	38	197	233	5	0
Apr 10	814	41	158	217	4	0
May 10	737	339	241	178	9	0
Jun 10	2294	154	146	178	6	0
July 10	37825	380	410	319	13	0
Aug 10	547	662	437	407	13	0
Sep 10	263	116	125	167	1	4
Oct 10	71	207	296	308	5	2
Nov 10	702	338	251	270	15	5
Dec 10	8703	160	318	277	14	0
Jan 11	41	210	313	265	9	3
Feb 11	6674	59	295	254	2	12
Mar 11	816.6	161	379	274	6	1

Table 1d. Confiscations and policing effort on a monthly basis for the Kleinmond region.

	Confiscations (# abalone)	Vehicles inspected	Slipway inspections	Coastal patrols	Road blocks	Sea patrols
April 08	0	17	30	30	3	0
May 08	0	17	30	30	3	0
June 08	124	33	21	21	0	0
July 08	3	30	25	25	0	0
Aug 08	1	35	13	28	0	0
Sep 08	288	7	9	9	0	0
Oct 08	471	47	30	30	0	0
Nov 08	557	55	30	30	0	0
Dec 08	314	91	31	31	0	0
Jan 09	37	230	38	31	2	1
Feb 09	781	84	28	28	0	0
Mar 09	4	15	20	20	0	0
April 09	209	66	30	30	1	0
May 09	208	72	30	30	1	0
June 09	40	50	170	165	2	1
July 09	639	60	165	170	0	0
Aug 09	168	130	170	180	1	0
Sep 09	430	45	16	18	0	0
Oct 09	269	60	31	31	1	0
Nov 09	767	80	30	30	1	0
Dec 09	118	100	31	31	2	0
Jan 10	257	70	31	31	0	1
Feb 10	144	105	28	28	2	0
Mar 10	283	110	75	31	2	0
Apr 10	80	20	30	30	0	0
May 10	262	45	25	31	2	0
Jun 10	0	6	30	30	3	2
July 10	323	30	31	31	0	0
Aug 10	227	30	31	31	1	0
Sep 10	11	15	3	20	2	0
Oct 10	972	25	31	31	0	0
Nov 10	1099	25	31	31	2	0
Dec 10	280	25	31	31	0	0
Jan 11	190	20	93	31	0	0
Feb 11	1	20	93	28	0	0
Mar 11	177	6	31	14	0	0

Table 2. GLM parameter/coefficient (and standard error) estimates for the whole South Coast (Cape Town to Arniston) and Saldanha Bay.

	Policing effort (year factor)	Policing effort (linear)	Confiscations (year factor)	Confiscations (linear)
January	0.542 (0.158)	0.532 (0.157)	-0.295 (0.617)	-0.333 (0.603)
February	0.132 (0.172)	0.113 (0.171)	-0.061 (0.579)	-0.138 (0.566)
March	0.074 (0.174)	0.045 (0.174)	-0.191 (0.599)	-0.305 (0.587)
April	0.264 (0.179)	0.209 (0.173)	-0.374 (0.727)	-0.423 (0.698)
May	0.235 (0.180)	0.171 (0.174)	0.405 (0.589)	0.318 (0.557)
June	0.059 (0.187)	-0.015 (0.181)	-0.132 (0.676)	-0.257 (0.643)
July	0.381 (0.174)	0.298 (0.167)	0.973 (0.529)	0.810 (0.492)
August	0.508 (0.170)	0.415 (0.163)	0.799 (0.544)	0.598 (0.507)
September	-0.301 (0.206)	-0.403 (0.199)	-0.694 (0.810)	-0.934 (0.774)
October	0.040 (0.176)	0.058 (0.175)	0.164 (0.548)	0.241 (0.536)
November	0.036 (0.176)	0.045 (0.175)	-0.514 (0.659)	-0.476 (0.644)
December	0	0	0	0
Time (yr^{-1})	—	0.113 (0.042)	—	0.460 (0.151)
2008	-0.189 (0.114)	—	-1.024 (0.433)	—
2009	-0.064 (0.084)	—	-0.679 (0.306)	—
2010	0	—	0	—
2011	0.193 (0.105)	—	0.143 (0.368)	—
coastal	0.066 (0.108)	0.066 (0.107)	—	—
road	-3.533 (0.174)	-3.533 (0.173)	—	—
sea	-4.996 (0.177)	-4.996 (0.176)	—	—
slipway	-0.189 (0.103)	-0.189 (0.102)	—	—
vehicles	0	0	—	—

Table 3. GLM parameter/coefficient (and standard error) estimates for Zones A to D.

	Policing effort (year factor)	Policing effort (linear)	Confiscations (year factor)	Confiscations (linear)
January	0.488 (0.216)	0.497 (0.215)	-0.390 (0.750)	-0.413 (0.718)
February	0.067 (0.236)	0.087 (0.236)	-0.017 (0.679)	-0.064 (0.650)
March	0.061 (0.237)	0.09 (0.237)	-0.004 (0.676)	-0.075 (0.649)
April	0.047 (0.242)	0.046 (0.236)	-0.262 (0.805)	-0.325 (0.755)
May	-0.151 (0.254)	-0.142 (0.247)	0.550 (0.661)	0.463 (0.610)
June	-0.033 (0.247)	-0.014 (0.239)	-0.069 (0.763)	-0.179 (0.710)
July	0.184 (0.236)	0.213 (0.227)	0.138 (0.723)	0.005 (0.669)
August	0.136 (0.238)	0.174 (0.229)	1.004 (0.613)	0.847 (0.558)
September	-0.445 (0.274)	-0.397 (0.265)	-0.504 (0.868)	-0.684 (0.810)
October	-0.002 (0.240)	-0.022 (0.240)	0.426 (0.615)	0.473 (0.589)
November	-0.025 (0.242)	-0.035 (0.241)	-0.363 (0.746)	-0.340 (0.715)
December	0	0	0	0
Time (yr^{-1})	—	-0.117 (0.058)	—	0.281 (0.164)
2008	0.230 (0.155)	—	-0.574 (0.465)	—
2009	0.235 (0.116)	—	-0.365 (0.342)	—
2010	0	—	0	—
2011	-0.005 (0.156)	—	0.187 (0.424)	—
coastal	0.132 (0.124)	0.132 (0.124)	—	—
road	-3.585 (0.225)	-3.585 (0.225)	—	—
sea	-5.224 (0.197)	-5.224 (0.196)	—	—
slipway	-0.306 (0.121)	-0.306 (0.121)	—	—
vehicles	0	0	—	—

Table 4. GLM parameter/coefficient (and standard error) estimates for Zones E to G.

	Policing effort (year factor)	Policing effort (linear)	Confiscations (year factor)	Confiscations (linear)
January	0.352 (0.197)	0.321 (0.196)	-0.085 (0.789)	-0.190 (0.841)
February	0.018 (0.212)	-0.043 (0.212)	-0.183 (0.811)	-0.394 (0.866)
March	-0.019 (0.214)	-0.110 (0.214)	-0.940 (1.030)	-1.260 (1.100)
April	0.155 (0.232)	0.070 (0.226)	-1.020 (1.420)	-0.860 (1.500)
May	0.377 (0.220)	0.261 (0.213)	-0.570 (1.200)	-0.520 (1.250)
June	-0.175 (0.254)	-0.322 (0.247)	-0.430 (1.140)	-0.480 (1.190)
July	0.448 (0.217)	0.271 (0.208)	2.150 (0.671)	1.994 (0.661)
August	0.639 (0.208)	0.432 (0.199)	-1.550 (1.780)	-1.810 (1.880)
September	-0.251 (0.260)	-0.489 (0.251)	-2.480 (2.730)	-2.850 (2.890)
October	-0.012 (0.214)	0.049 (0.214)	-1.310 (1.180)	-1.100 (1.260)
November	-0.015 (0.214)	0.015 (0.214)	-1.050 (1.080)	-0.950 (1.150)
December	0	0	0	0
Time (yr^{-1})	—	0.366 (0.055)	—	1.268 (0.335)
2008	-0.746 (0.159)	—	-3.730 (1.670)	—
2009	-0.466 (0.111)	—	-1.992 (0.631)	—
2010	0	—	0	—
2011	0.258 (0.127)	—	0.153 (0.568)	—
coastal	-0.136 (0.182)	-0.136 (0.182)	—	—
road	-3.474 (0.209)	-3.474 (0.209)	—	—
sea	-3.940 (0.260)	-3.940 (0.259)	—	—
slipway	-0.069 (0.158)	-0.069 (0.158)	—	—
vehicles	0	0	—	—

Table 5. GLM parameter/coefficient (and standard error) estimates for the Kleinmond region.

	Policing effort (year factor)	Policing effort (linear)	Confiscations (year factor)	Confiscations (linear)
January	0.732 (0.332)	0.732 (0.355)	-0.386 (0.825)	-0.399 (0.859)
February	0.081 (0.378)	0.081 (0.405)	0.263 (0.698)	0.236 (0.727)
March	-0.206 (0.407)	-0.206 (0.437)	-0.428 (0.836)	-0.469 (0.871)
April	-0.118 (0.412)	-0.198 (0.440)	-0.532 (0.992)	-0.790 (1.020)
May	0.034 (0.396)	-0.047 (0.422)	-0.045 (0.850)	-0.321 (0.873)
June	1.007 (0.330)	0.926 (0.348)	-1.100 (1.230)	-1.390 (1.270)
July	0.396 (0.365)	0.315 (0.386)	0.674 (0.713)	0.371 (0.724)
August	0.567 (0.353)	0.486 (0.372)	-0.217 (0.895)	-0.533 (0.916)
September	-0.808 (0.510)	-0.889 (0.542)	0.393 (0.758)	0.064 (0.770)
October	-0.252 (0.412)	-0.251 (0.442)	0.877 (0.625)	0.904 (0.651)
November	-0.096 (0.395)	-0.096 (0.423)	1.225 (0.597)	1.238 (0.622)
December	0	0	0	0
Time (yr^{-1})	—	0.0002 (0.094)	—	0.161 (0.182)
2008	-0.820 (0.286)	—	-0.953 (0.766)	—
2009	0.321 (0.162)	—	0.342 (0.350)	—
2010	0	—	0	—
2011	-0.388 (0.271)	—	0.492 (0.404)	—
coastal	-0.274 (0.193)	-0.274 (0.207)	—	—
road	-4.103 (0.286)	-4.103 (0.306)	—	—
sea	-5.927 (0.246)	-5.927 (0.264)	—	—
slipway	-0.177 (0.200)	-0.177 (0.214)	—	—
vehicles	0	0	—	—

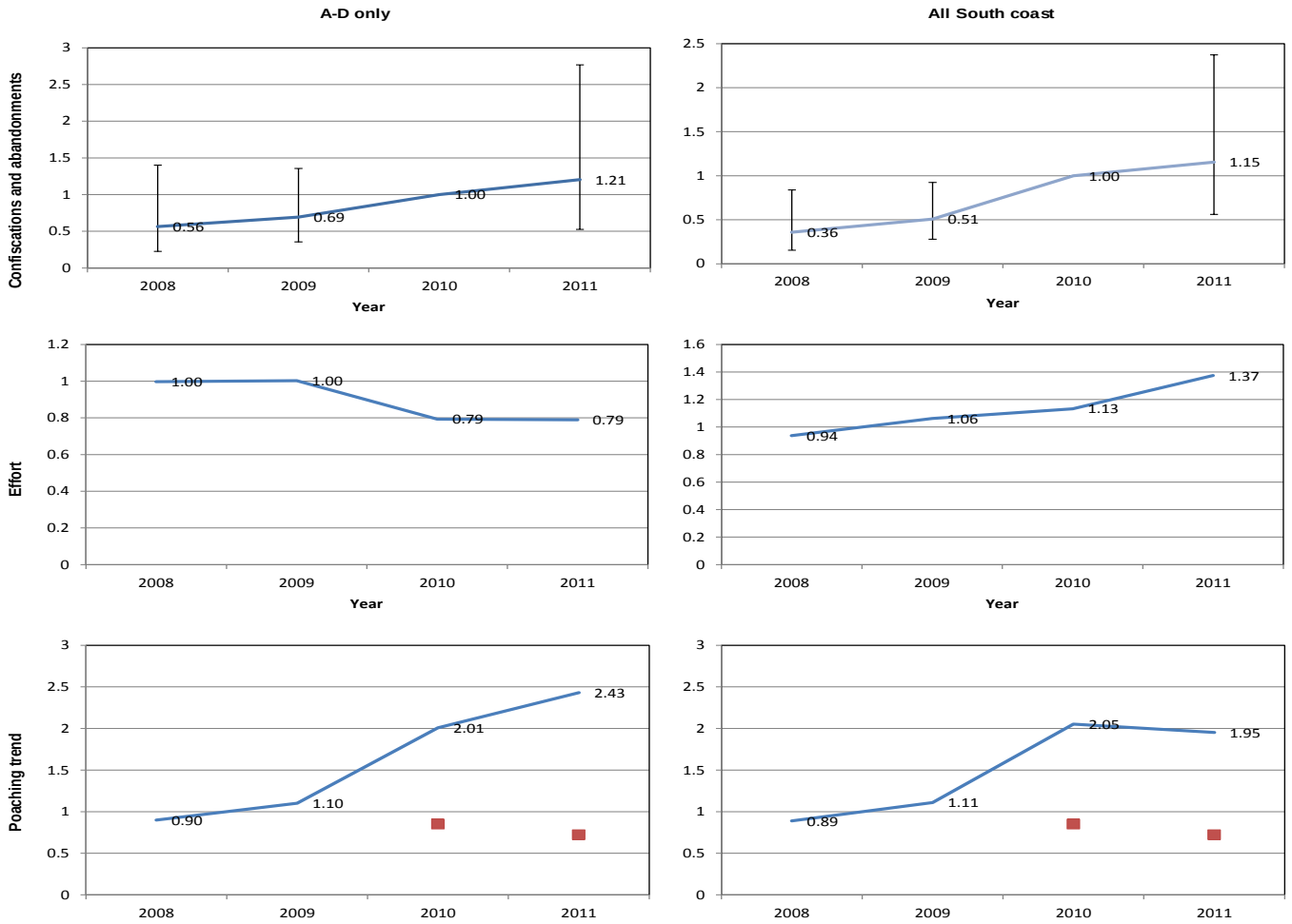

Figure 1. Comparison of estimates of annual factors from the categorical model of equation (2) where these are estimated for each Model-year. Results are shown for confiscations (and abandonments) and for policing effort, with the lowest pair of plots reflecting the ratios as an index of the annual level of poaching, and the squares reflecting the 15% annual decrease in poaching sought under the current abalone recovery plan. The left side plots are for Zones A-D only, whereas the right side plots are for the whole South Coast. The confiscation plots are normalised to the 2010 values with 95% CIs shown for the other Model-years. The effort and poaching index are normalised to their 2008-2009 average values.

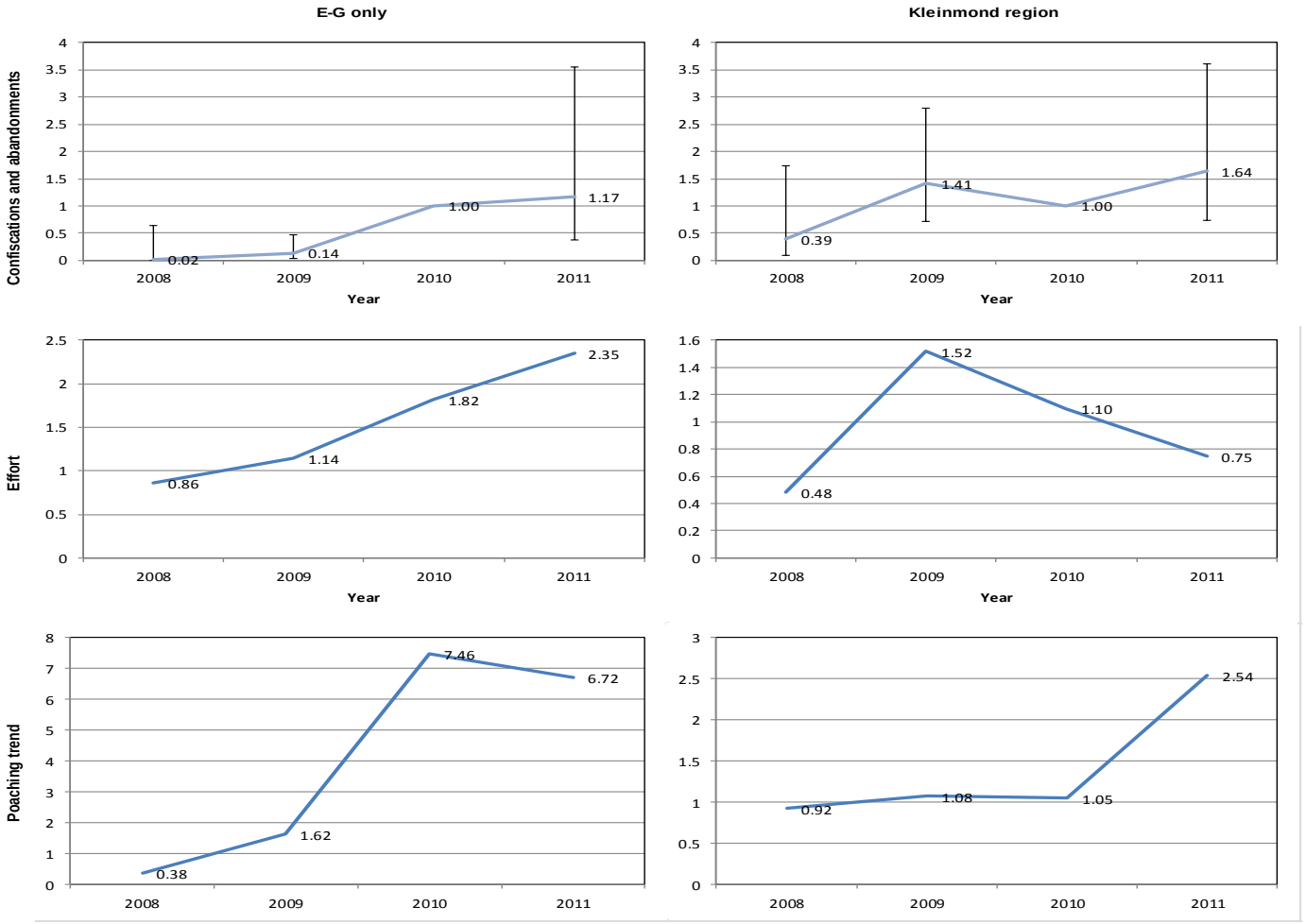

Figure 2. Comparison of estimates of annual factors from the categorical model of equation (2) where these are estimated for each Model-year. Results are shown for confiscations (and abandonments) and for policing effort, with the lowest pair of plots reflecting the ratios as an index of the annual level of poaching. The left side plots are for Zones E-G only, whereas the right side plots are for the Kleinmond region. The confiscation plots are normalised to the 2010 values with 95% CIs shown for the other Model-years. The effort and poaching index are normalised to their 2008-2009 average values.