Participatory stock assessment of Abalone in Zones E and G

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Introduction and objectives

The stock assessment for abalone is significantly hampered by insufficient information on the levels of poaching in each management zone. To assist with our understanding of resource dynamics, stakeholder interviews were conducted to obtain information on the levels of poaching taking place and trends in magnitude over time. This participatory approach represented a pilot study into the use of interview data to inform modeling of the resource. As such, effort was concentrated on Zones E and G. These are two of the least productive Zones with consequently fewer divers operating.

The investigation was split into two. The first part was to assess and understand the types of information available for potential inclusion in the modeling process [1]. The second part was actual execution of the participatory stock assessment using the information collected. This report details the outcome from Part 2.

Interview data relevant to a participatory stock assessment

The collection of interview data constituting Part 1 of this study has been reported elsewhere [1]. Here we briefly summarise the conclusions reached.

Four sources of data would be potentially useful to the participatory stock assessment executed here: poaching intensity, poaching trends, spatial distribution of poaching effort and the illegal CPUE. We were unable to collect sufficient information on either the poaching intensity or the illegal CPUE. In contrast abundant information on trends in poaching magnitude over time and the spatial distribution of effort was obtained during stakeholder interviews. The spatial information is not included in the participatory assessment presented here as it represents an additional layer of complexity not yet attempted. Instead we focus on using trend information to inform the stock assessment.

Current status of the stock assessment

A discrete-time Schaefer model of biomass dynamics is currently used in the stock assessment for abalone in Zones E and G [3, 2]. Parameter estimates are obtained through fitting to the commercial CPUE series within a Bayesian framework. It is notable that model fit is poor for both Zones indicating that either the model is inadequate or that there are conflicts in the data. Catch and CPUE data for both Zones is shown in Tables 1 and 2. Figures 1 and 2 provide an illustration of the catch series currently used in the stock assessment.

Methods

Poaching trends

Zone E Poaching was thought to have increased gradually since the first landings were recorded. It then rapidly escalated to high levels in the mid-1990's when the market value of abalone improved, peaking between 1998 and 2000. Much of this poaching was thought to have occurred under the guise of recreational fishing. Levels consequently began to drop in 2000 when permit regulations improved and again in 2003 when the recreational fishery was closed. Poaching activity was further reduced after establishment of the Cape Pensinsula marine protected area in 2004 and is thought to currently be low.

Zone G Poaching trends in this Zone were thought to be similar to Zone E, but with a lag of approximately one year. However in contrast to the other Zone, poaching has remained high in recent years.

Model fit

The model used is exactly as described in the stock assessment methodology [3]. It is fitted to commercial CPUE data with commercial catch in this case providing the only additional input. Instead of inputing the illegal and recreational catch into the model, we estimate their combined value. The justification for this approach is two-fold. Firstly, the recreational catch is by far the dominant catch series (Figures 1 and 2), and the poor model fits when recreational catch is input suggests that it may be inaccurate. Its inclusion in the model is therefore likely to disrupt any attempts to estimate additional catches during the model fit. The unreliability of the recreational catch record was also asserted by the stakeholders interviewed. However there was also perceived to be an association between recreational and illegal fishing, particularly in Zone E. We therefore sought to estimate the combined recreational and illegal catches, which we term collectively as 'Non-commercial' catch.

The non-commercial catch was assumed to follow the trends for each Zone described above. Specifically it was represented by interpolating between temporally fixed points. Four points describe the catch trend: initial catch (prior to 1980), catch in the mid 1990's (Zone E: 1995; Zone G: 1996), maximum catch (Zone E: 1998-2000; Zone G: 1999-2001), and final catch (post 2003). We assume initial and final catch values to be fixed. For Zone G the final catch was set equal to the maximum catch. During Bayesian model fitting, the remaining two catch values were sampled from uniform prior distributions. The catch trend was calculated using these values and input into the model.

Non-commercial catch parameter specifications were therefore specified (in tonnes) as follows:

	Zone E		Zone G	
$initial.catch$	1977-1980	10	1977-1980	5
$mid.catch$	1995	$U(5, 120)$	1996	$U(5, 80)$
$max.catch$	1998-2000	$U(5, 120)$	1999-2007	$U(5, 80)$
$final.catch$	2003-2007	1.4		

Initial catches were set as approximately equal to the recreational catch values recorded for 1977 (Tables 1 and 2). Maximum prior $mid.catch$ and $max.catch$ values were set as approximately equal to the maximum recorded recreational catch for each Zone. Lower bounds were arbitrary. The $final.catch$ for Zone E matches current perceptions among stakeholders as to the magnitude of poaching currently taking place [4, 5]. Attempts to estimate the $initial.catch$ and $final.catch$ in addition to the other catch parameters proved unsuccessful. The prior distribution of r was identical to that used for the stock assessment, specifically $r \sim U(0.1, 0.3)$. The prior distribution for K had a reduced lower bound with $K \sim U(0.01, 3)$ in units of 10^3 tonnes. These large priors, on K, $mid.catch$ and $max.catch$ allowed ample flexibility for the model to explore and locate a suitable fit. However a trade off exists in that the wider the sampled prior distributions the more samples are required to adequately explore the enclosed parameter space. Unfortunately the number of samples used during Bayesian estimation of parameter values was limited by time and computing restrictions to 100,000.

In order to compare the stock assessment model with the participatory model presented here, model fit was estimated using the Akaike information criterion. This is calculated as $AIC = -2logLk + 2p$ where $logLk$ is the log-likelihood [3] and p is the number of parameters estimated (three for the stock assessment model and five for the participatory model). The model with the lowest AIC is considered to provide the best representation of the data.

Biomass projections

We present biomass projections for each Zone assuming an unchanged or zero TAC. Current TAC values are listed in Tables 1 and 2. Estimated non-commerical catches are assumed to be unchanged during the projection period (i.e. equal to $final.catch$).

Results

A discrete Schaefer model was fitted to CPUE data within a Bayesian framework. Inputs into the model included commercial catches only. Non-commercial (recreational plus illegal) catches were also estimated during the model fitting process, in addition to the model parameters r and K. We present the results of this model fit for each Zone, alongside values obtained from the preliminary 2007 stock assessment (referred to as the Reference case) [3]. We refer to the current model (in which the non-commercial catch is estimated) as the Participatory case.

Zone E

Parameter estimates and other model outputs (described elsewhere [3]) are given in Table 3. It is notable that estimates of K are substantially smaller for the participatory case. Figure 3 shows the catch series estimated during the model fit and Figure 4 the posterior probability distributions of estimated parameters. Of particular interest is Figure 5, which shows the CPUE fit for the participatory model, compared to the reference (stock assessment) model. Although the fit to early years is less satisfactory, the participatory model has a clearly improved fit to the CPUE time series for recent years. This is reflected by the AIC values calculated for the reference ($AIC = -14.82$) and participatory ($AIC = -22.59$) cases, which suggest that the participatory model provides a more accurate representation of the data.

Biomass projections assuming an unchanged TAC are compared in Figure 6. The most noticeable difference between the participatory and reference case models is that the former estimates a substantially lower overall biomass of abalone. Projections for the participatory model under different catch scenarios are shown in Figure 7, indicating a positive resource trajectory.

Zone G

Parameter estimates and other model outputs are given in Table 4. Figure 8 shows the catch series estimated during the model fit and Figure 9 the posterior probability distributions of estimated parameters. The CPUE fit for the participatory model, compared to the reference model is shown in Figure 10. The participatory model again shows an improved fit to the CPUE time series, more accurately representing the downward trend in CPUE in recent years. AIC values for the reference ($AIC = -16.78$) and participatory ($AIC = -21.65$) cases again support this inference.

Biomass trajectories for the participatory and reference models are compared in Figure 11. The participatory model estimates a higher overall biomass of abalone but predicts that stocks will decline under the current catch regime. Figure 12 illustrates the predicted outcome under different catch scenarios.

Conclusion

In Part 1 of this study we collected information on the trends in poaching over time through interviews with stakeholders in Zones E and G. In this paper, representing Part 2 of the study, we have attempted to incorporate this information into the stock assessment.

We estimated the combined recreational and illegal catch during fit of the model to commercial CPUE data. Co-estimating non-commercial catch alongside other model parameters allowed the model a high degree of flexibility to explore the parameter space within the bounds stipulated by the non-commercial catch trend. We established *a priori* (through the stakeholder interviews) that these trends are likely to provide a reasonable reflection of actual catches. The improved model fits resulting from this approach can therefore be justified as consistent with available information. Although error bounds reported for the biomass projections are large, this is likely due to the increased parameter space explored by the model. Sampling a larger number of times from the prior distributions during Bayesian estimation may improve model accuracy.

It is notable that biomass predictions from the participatory assessments are different from the reference cases reported in the stock assessments. For Zone E the overall biomass is substantially reduced, although predictions of positive population growth are unaffected. For Zone G the overall biomass is similar although there are implications for predicted resource dynamics. The participatory assessment clearly indicates a negative resource trajectory, suggesting that the sustainability of abalone populations in this Zone is threatened.

Acknowledgements

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References

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Table 1: Catch data: **Zone E**. All catches are in kilograms.

Model Year	TAC	no. datapoints	CPUE	Comm. Catch	Rec. Catch	Illegal Catch
1977				19000	14061	0
1978				8000	16873	0
1979				2000	19685	0
1980		19	1.36	8861	22497	4620
1981		8	1.42	4852	25309	3016
1982				360	28121	2941
1983				278	30934	3121
1984		6	1.66	5447	33746	4325
1985		158	1.47	74563	36558	12416
1986		9	1.41	3681	39370	4330
1987	20000	42	1.25	11840	42182	5916
1988	20000	16	1.18	4975	44994	5092
1989	20000	42	1.35	17820	47806	6770
1990	20000	19	1.07	4572	50619	5538
1991	10000	35	1.03	6591	53431	6007
1992	0			0	62800	6280
1993	0			0	121300	12130
1994	0			0	79900	7990
1995	0			0	78000	7800
1996	0			0	67600	6760
1997	0			0	74400	7440
1998	5000			0	37200	3970
1999	5000	24	1.12	3303.4	12400	4000
2000	5000	30	1.08	4964.2	13000	4000
2001	5300	24	0.99	4057.2	14000	4000
2002	13000	73	0.79	10136.9	29100	4080
2003	13000	43	0.86	5963	18500	2000
2004	15000	138	0.78	14353	0	1290
2005	15000	127	0.77	14110	0	1510
2006	12000	112	0.81	11962	0	1400
2007	12000	69	0.89	8406	0	1400

Table 2: Catch data: **Zone G**. All catches are in kilograms.

Model Year	TAC	no. datapoints	CPUE	Comm. Catch	Rec. Catch	Illegal Catch
1977				66000	4528	0
1978				19000	5433	0
1979				11000	6339	0
1980		9	1.33	4587	7244	1624
1981		10	1.58	5293	8150	3515
1982		18	1.44	13669	9055	3806
1983		8	1.24	3926	9961	1389
1984				206	10867	1107
1985				502	11772	1227
1986		89	1.43	41729	12678	5441
1987	30000	76	1.41	30652	13583	4424
1988	30000	95	1.27	32539	14489	4703
1989	30000	98	1.13	22653	15394	3805
1990	0			0	16300	1630
1991	0			0	17205	1721
1992	0			0	15900	1590
1993	0			0	47400	4740
1994	0			0	48500	4850
1995	0			0	78300	7830
1996	0			0	59800	5980
1997	0			0	57600	11520
1998	15000	91	1.04	6182	39600	9649
1999	15000	17	1.24	2232	6600	4000
2000	15000	38	0.99	5381	6300	4000
2001	15000	95	0.84	12359.7	6000	4000
2002	25500	106	1.01	20469.7	6600	5587
2003	25000	116	1.03	17378.5	6400	8000
2004	27000	151	0.79	19947	0	8000
2005	27000	173	0.77	22302	0	8000
2006	22000	155	0.8	18633	0	8000
2007	18000	54	0.92	3935	0	8000

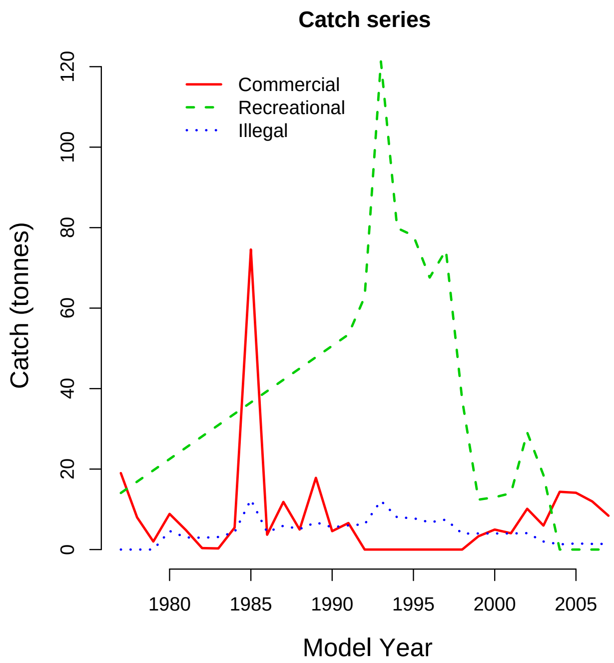

Figure 1: Catch series: **Zone E**.

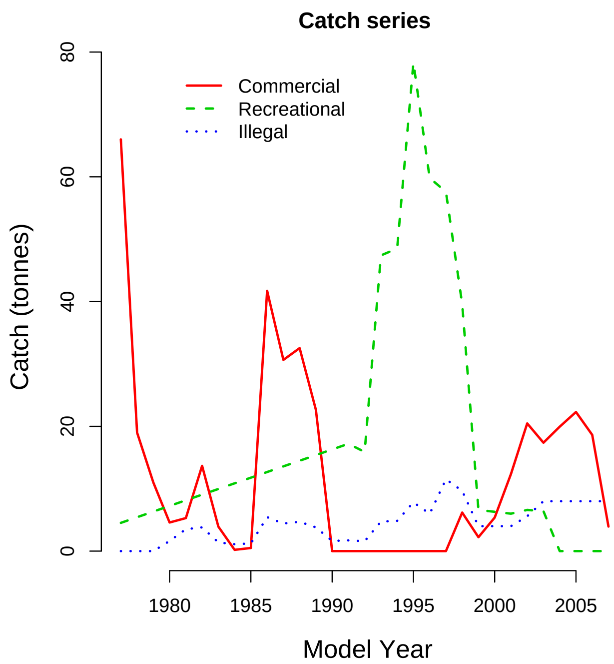

Figure 2: Catch series: **Zone G**.

Table 3: Model outputs: **Zone E**. Median of the posterior density and lower and upper HPD intervals are given with estimated non-commercial catch and for the reference case.

Output	Estimate catch			Reference		
	Median	Lower	Upper	Median	Lower	Upper
K	766	458	1703	1547	1284	1911
r	0.12	0.10	0.17	0.11	0.1	0.15
q	2.09E-06	8.65E-07	3.94E-06	1.03E-06	7.47E-07	1.32E-06
σ	0.11	0.09	0.13	0.14	0.14	0.17
$mid.catch$	14	6	70			
$max.catch$	60	35	113			
y_{2007}	434	208	1116	954	734	1384
$sust.catch$	23	14	46	41	38	44
$MSYL$	383	229	851	774	642	956
$depletion$	0.55	0.45	0.68	0.62	0.54	0.74

Table 4: Model outputs: **Zone G**. Median of the posterior density and lower and upper HPD intervals are given with estimated non-commercial catch and for the reference case.

Output	Estimate catch			Reference		
	Median	Lower	Upper	Median	Lower	Upper
K	1217	734	1861	1075	830	1400
r	0.17	0.11	0.28	0.12	0.1	0.17
q	1.23E-06	7.72E-07	2.16E-06	1.46E-06	9.97E-07	1.99E-06
σ	0.10	0.10	0.12	0.13	0.13	0.16
$mid.catch$	56	28	77			
$max.catch$	60	31	78			
y_{2007}	661	364	1106	653	464	1016
$sust.catch$	52	31	71	30	27	34
$MSYL$	608	367	930	537	415	700
$depletion$	0.54	0.47	0.63	0.61	0.52	0.74

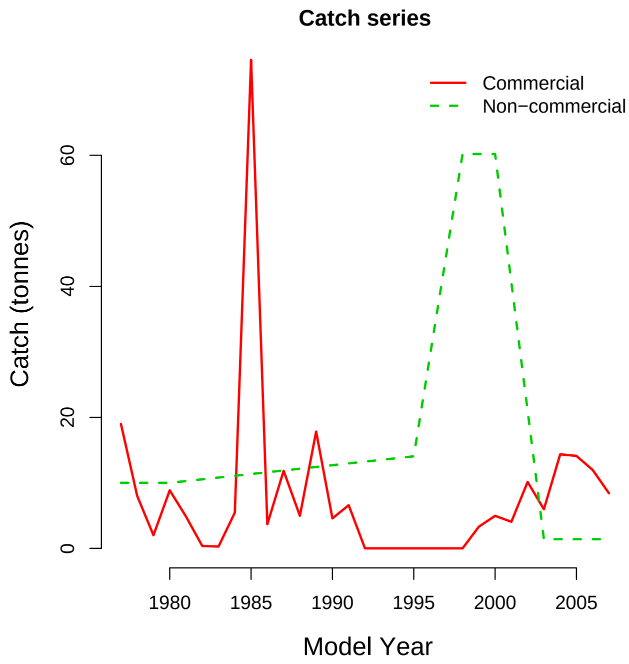

Figure 3: Estimated non-commercial catch: **Zone E**.

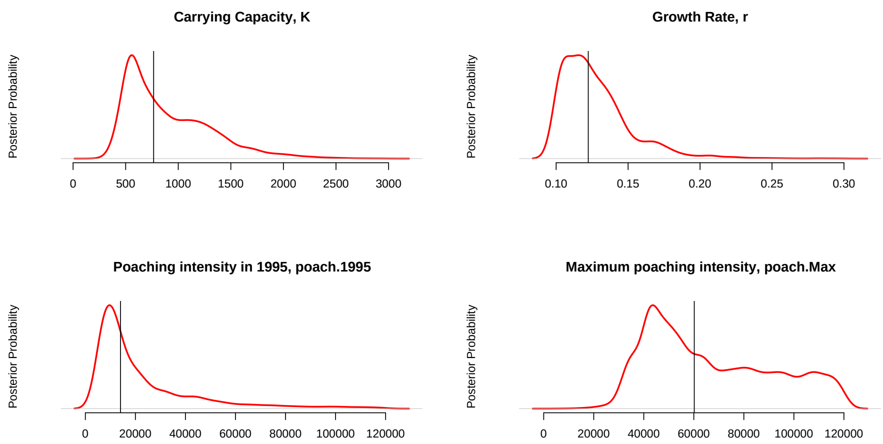

Figure 4: Posterior probability distributions: **Zone E**.

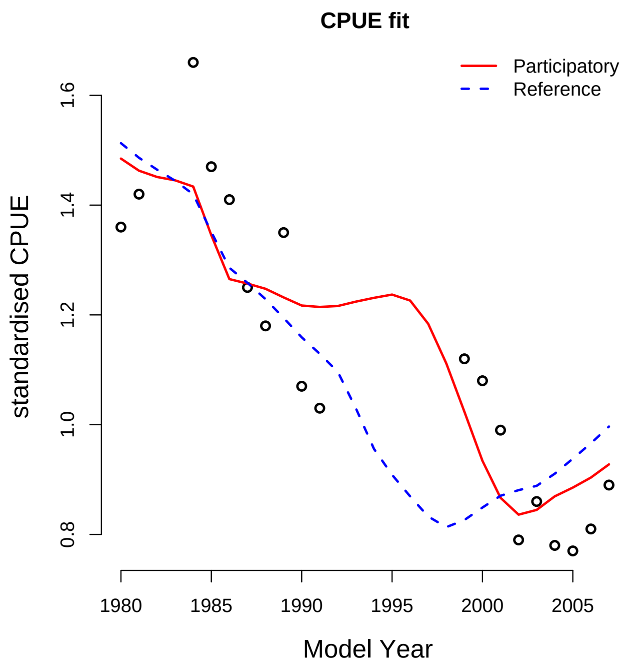

Figure 5: CPUE fits for Participatory and Reference models: **Zone E**.

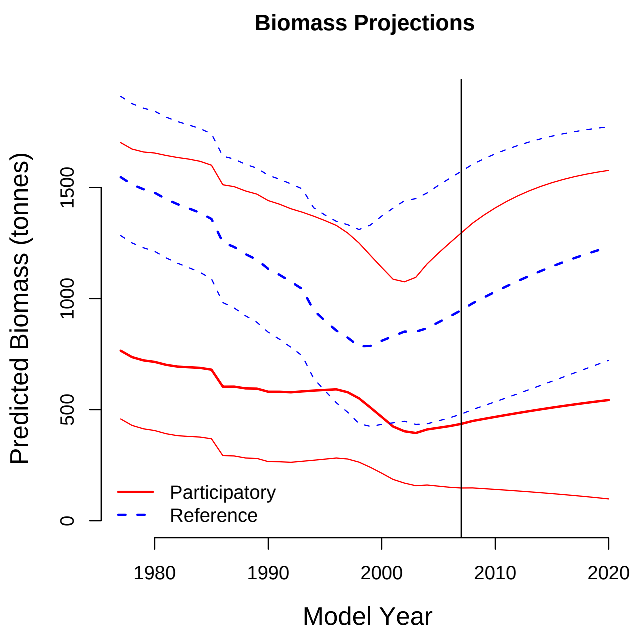

Figure 6: Comparison of biomass projections for Participatory and Reference models: **Zone E**.

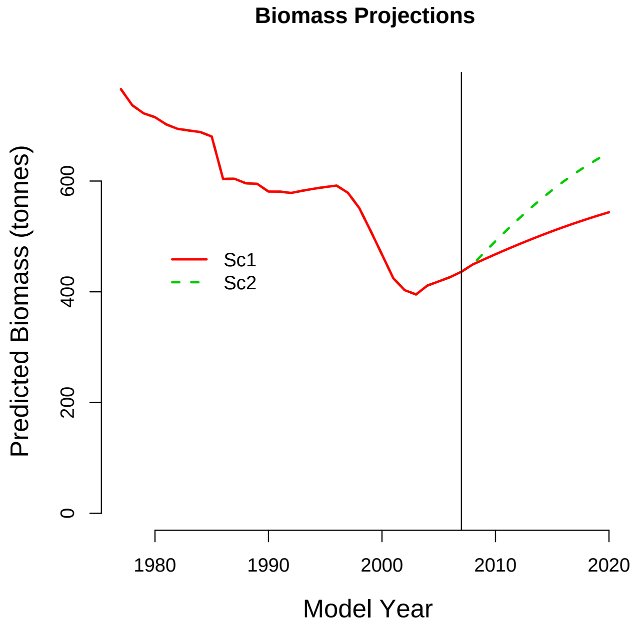

Figure 7: Biomass projections for Participatory model: **Zone E**. Scenario 1: TAC unchanged; Scenario 2: TAC zero. Non-commercial catch during projections was assumed to be equal to $final.catch$ for both scenarios.

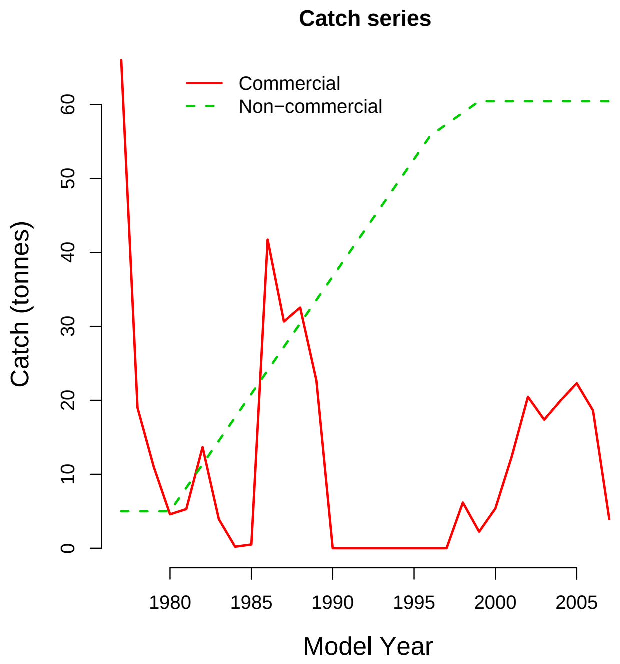

Figure 8: Estimated non-commercial catch: **Zone G**.

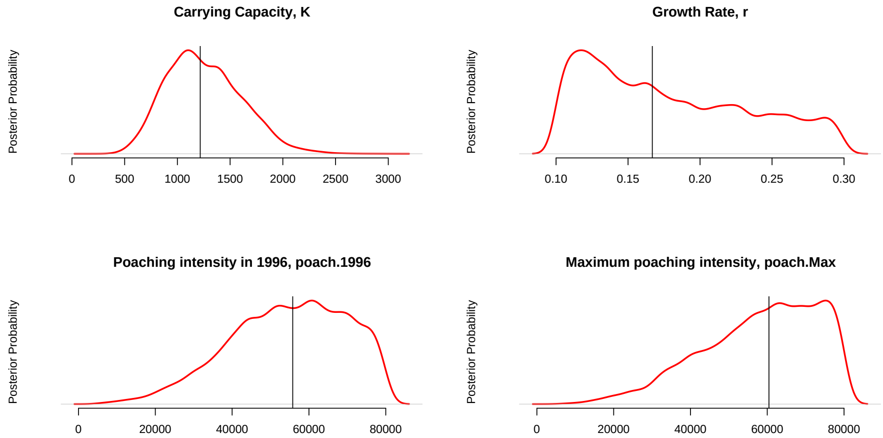

Figure 9: Posterior probability distributions: **Zone G**.

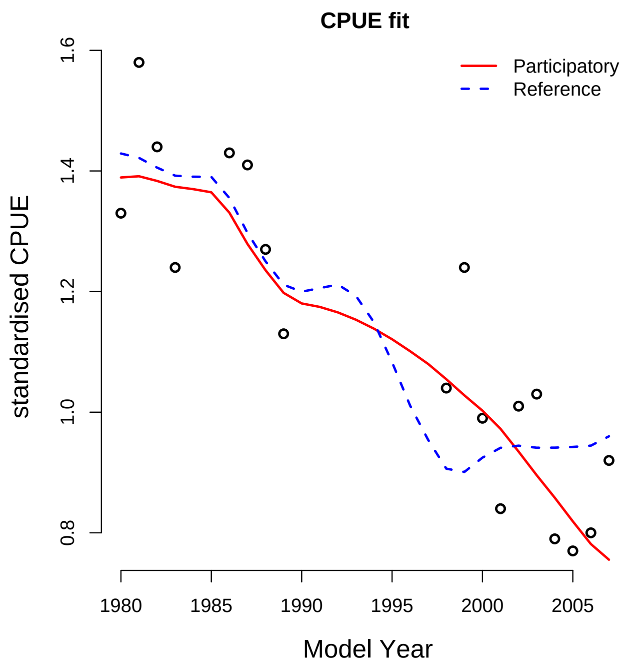

Figure 10: CPUE fits for Participatory and Reference models: **Zone G**.

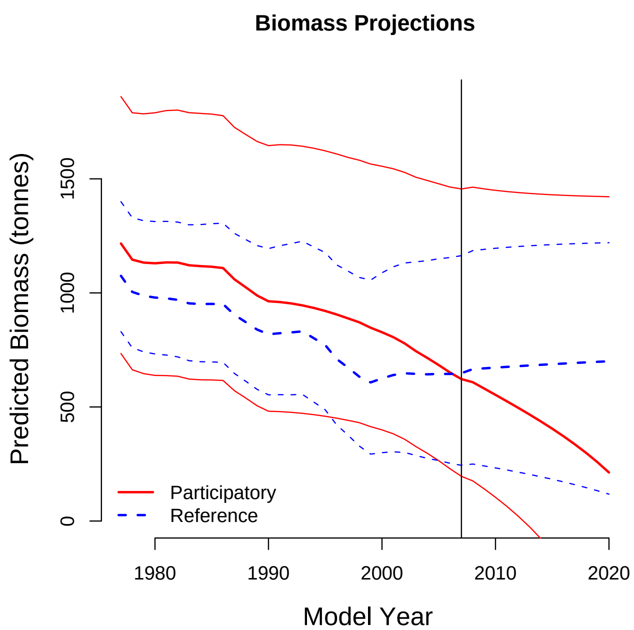

Figure 11: Comparison of biomass projections for Participatory and Reference models: **Zone G**.

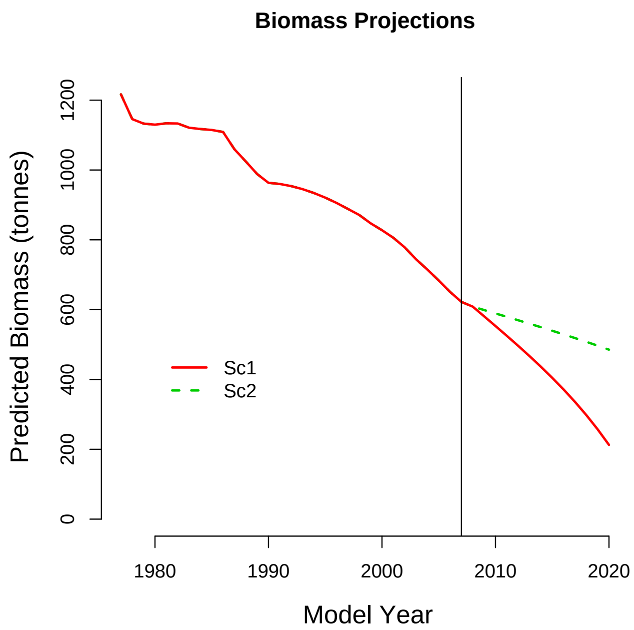

Figure 12: Biomass projections for Participatory model: **Zone G**. Scenario 1: TAC unchanged; Scenario 2: TAC zero. Non-commercial catch during projections was assumed to be equal to $final.catch$ for both scenarios.