Participatory assessment of the South African abalone resource and its impact on predicted population trajectories

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Illegal harvesting is a cause for concern in many of the world's fisheries. Over the last decade, the abalone resource in South Africa has come under severe fishing pressure, largely because of increased and unmitigated levels of poaching. The unquantified illegal exploitation of this resource is a major impediment to management, because understanding of abalone population dynamics is affected. Incorrect assessments of population abundance could lead to inadequate attempts by management to stem the decline. Here, population trends along the west coast of South Africa are investigated. A simple discrete-time logistic model was used to estimate parameters within a maximum likelihood statistical framework by fitting to available catch rate data. To address the problem of unknown levels of illegal catch, interview data were collected on non-commercial catch trends and the model was structured to allow this catch to be estimated during the fitting process. The results show that such a participatory approach to stock assessment can lead to an improved understanding of resource dynamics, illustrating the benefit this approach may have for management.

Introduction

Several abalone stocks worldwide have shown or continue to show severe declines as a result of either environmental factors or overfishing.[1,2] The demand for abalone is partly attributable to its reputed aphrodisiac qualities (China) and traditional useage as a high-status product for important ceremonial events (Japan).[3] The resultant high commercial value has rendered abalone a prime target for illegal fishing. This is a major concern similarly facing other high-value resources in the world's oceans including, for example, the long-lived and slow growing Patagonian toothfish (*Dissostichus eleginoides*).[4] Indeed, the international fisheries management community has recently accorded high priority to curbing illegal, unreported and unregulated (IUU) fishing activities that are contributing to the decline of fish stocks.[5,6] To quantify the full impact of a fishery on both the target stock itself and the ecosystem, it is essential to have an estimate of total extractions, despite the considerable technical difficulties associated with determining IUU catches.[7]

The South African abalone, *Haliotis midae,* is harvested in the Western Cape from Cape Agulhas to St Helena Bay, sustaining one of the oldest commercial abalone fisheries in the world. Abalone populations are managed separately within seven distinct zones (referred to as Zones A–G). Historically, the south coast (Zones A–D) typically yielded 80–90% of the annual total allowable catch (TAC),[8] although this proportion has fallen in recent years. The fishery peaked in 1965 with catches of 2.7 thousand tonnes and continued to produce consistent yields until the early 1990s. However, the resource has since come under severe fishing pressure. Due to consequential population declines, the fishery has now reached the point of commercial collapse in some areas. The recreational fishery was closed indefinitely in 2003 and the TAC dropped to 125 tonnes for the 2006/07 season, with three zones (A, C and D) closed to commercial fishing.

Although ecosystem changes have contributed to the decline of abalone populations in zones C and D,[9,10] the current situation is primarily the result of rampant levels of poaching. *H. midae* is restricted to shallow beds of kelp (*Ecklonia maxima*) that are easily accessible from the shore. When combined with its high commercial value, this makes abalone particularly vulnerable to illegal exploitation by both traditional fishers unable to obtain formal access to the fishery, and criminal elements.[11,12]

Management measures are informed by quantitative modelling of the abalone resource. In zones A–D, population dynamics are evaluated and predictions made using an age-structured production model[13] that uses catch per unit effort (CPUE) as an index of population abundance, alongside fishery-independent survey data and a range of other data sources. Here we focus on zones E and G, which cover the stretch of coast from Cape Point to St Helena Bay. Because of their lower commercial yield and the absence of length–frequency information in this region, the data available for these zones are insufficient to apply an age-structured model, so that a simple logistic model of population growth is currently used in the annual stock assessment.[14] Annual catches are an important component of these models and the accuracy of model predictions is impeded by a lack of reliable information concerning the levels of illegal catch. Indeed, model fits to the available catch rate data for zones E and G, undertaken during a recent stock assessment, were extremely poor.[14]

In this investigation we supplemented the data available for modelling of resource dynamics by conducting stakeholder interviews. This participatory process provided additional information that was incorporated into the model. Focusing on zones E and G we illustrate how a participatory approach can affect model predictions of biomass dynamics, with implications for attempts to achieve the management goal of sustainable resource use.

Methods

The current stock assessments of abalone in zones E and G (referred to here as the Reference model) are based on a logistic model of population dynamics.[14] In this investigation the Reference model is compared to a new model (referred to as the Participatory model), which incorporates information obtained from stakeholder interviews, to assess the benefits of this approach to the understanding of resource dynamics.

Data

Reference model

Information on catch and effort from zones E and G was obtained from Marine and Coastal Management (MCM), a branch of the Department of Environmental Affairs and Tourism

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that is responsible for management of South Africa's marine resources. Commerical catch is recorded at landing sites along the coast and Recreational catch estimated by an annual telephonic survey of recreational divers. Following discussions within the Abalone Scientific Working Group convened by MCM, the illegal catch is broadly assumed to be 10% of the Commercial plus Recreational catches since 1980, increasing to 20% for Zone G since 1997.[15] Minor modifications were made for recent years following consultation by MCM with representatives from the abalone fishing industry (A. Mackenzie, pers. comm.). The CPUE is calculated using the Commercial catch only, as this is by far the most reliable record, and has been standardized using general linear modelling (GLM) techniques[16] to ensure that it more closely represents trends in population abundance. The data available for each zone are listed in Tables 2 and 3. The TACs for each year, first introduced in 1987, are also shown.

Participatory model

The Participatory model also uses the Commercial catch and CPUE data described in Tables 2 and 3. These data have been supplemented by stakeholder interviews, which were conducted to obtain information on the levels of poaching taking place and trends in magnitude over time. The South African Abalone Industry Association, Table Mountain National Park and MCM Compliance personnel participated in this exercise.

Stakeholders were unsure of the magnitude of poaching, but were confident of the changes in poaching intensity, particularly in Zone E. In this zone, poaching was considered by interviewees to have increased gradually since the first landings were recorded. It then rapidly escalated to high levels in the mid-1990s, 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 around 2000, when permit regulations became more restrictive (due to shortening of the season) and again in 2003, when the recreational fishery was closed. Poaching activity was further reduced by improved enforcement levels (facilitated by cooperation with local rights holders) and establishment of the Cape Pensinsula marine protected area in 2004. Poaching is currently thought to be low.

Poaching trends in Zone G were considered to be similar to Zone E, but with a lag of approximately one year. In contrast to Zone E, however, poaching is thought to have remained high with only slight decreases in recent years.

Population dynamics models

Reference model

The Reference model is a discrete-time Schaefer model[17] of population dynamics:

$$B_{n+1} = B_n + rB_n\left(1 - \frac{B_n}{K}\right) - C_n - R_n - P_n \tag{1}$$

$$I_n = qB_n e^{\varepsilon} = \hat{I}_n e^{\varepsilon} \tag{2}$$

where n is the model year, representing a season of fishing from October in year $n - 1$ to September in year n, with $\{n = 1977, 1978,..., 2007\}$; B_n is the population biomass in year n, assuming $B_{1977} = K$; r is the intrinsic growth rate; K is the carrying capacity; C_n is the annual commerical catch in year n; R_n is the annual recreational catch in year n; P_n is the annual illegal catch in year n; q is the catchability coefficient; and, I_n is an index of population size, in this case the GLM-standardized CPUE measured in kilograms per minute dived.

Observation error [Equation (2)] is assumed to have a log-normal distribution with $\varepsilon \sim N\ (0, \sigma^2)$. Process error is assumed to be negligible [i.e. no error term in Equation (1)].

The negative log-likelihood of the observed Commercial CPUE values is then given by:

$$-lnL(I|r,K,\sigma,q) = ln(\sigma) + \frac{\sum_{n=1977}^{2007}[ln(I_n) - ln(\hat{I}_n)]^2}{2\sigma^2} \tag{3}$$

with the maximum likelihood value of q provided by the closed form:

$$ln(\hat{q}) = \frac{1}{s}\sum[ln(I_n) - ln(B_n)], \tag{4}$$

where s is the number of years for which CPUE data are available.

Participatory model

The Participatory model is identical in all respects to the Reference model, except that instead of inputting the Illegal and Recreational catches, their combined value (termed collectively as the 'Non-Commercial' catch) is estimated. The model is therefore represented as:

$$B_{n+1} = B_n + rB_n\left(1 - \frac{B_n}{K}\right) - C_n - \widetilde{P}_n, \tag{5}$$

where $\widetilde{P}_n$ is the estimated 'Non-Commercial' catch for year n.

The model is fitted to CPUE data by maximum likelihood as described by Equations (3) and (4).

The justfification for this approach is twofold. First, the Recreational catch is by far the dominant catch series (Figs 1a and 2a), and fits when Recreational catch was input were poor (see Reference model fits Figs 3a and 4a), suggesting that it may be inaccurate. Inclusion of the Recreational catch series in the model would therefore likely disrupt any attempts to estimate illegal catches separately. 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. The Recreational and Illegal catch data used by the Reference model were therefore excluded and instead their combined value was estimated.

The Non-Commercial catch was assumed to follow the trends for each zone described during stakeholder interviews. Specifically, it was described by four parameters, each equal to the Non-Commercial catch over a specified period (Table 1). The Non-Commercial catch trend was completed by interpolating between these time periods to create the estimated vector of Non-Commercial catches, $\widetilde{\boldsymbol{P}}$.

Table 1. Parameters used to define the Non-Commercial catch trend. Each parameter represents a constant catch in tonnes over the stated period.

Zone E		Zone G	
Parameter	Period	Parameter	Period
$\tilde{P}_{1977:1980}$	1977–1980	$\tilde{P}_{1977:1980}$	1977–1980
P_{1995}	1995	P_{1996}	1996
$P_{1998:2000}$	1998–2000	$P_{1999:2001}$	1999–2001
$P_{2003:2007}$	2003–2007	P_{2007}	2007

Parameter estimation

All parameters, namely $\{K, r, \sigma, q\}$ for the Reference model and $\{K, r, \sigma, q, \widetilde{\boldsymbol{P}}\}$ for the Participatory model, were estimated within a maximum likelihood framework using AD-Model Builder v6.02 (Otter Research Ltd). Convergence was checked in each case. Confidence intervals were obtained from the likelihood profiles for each parameter. Likelihood theory states that for a

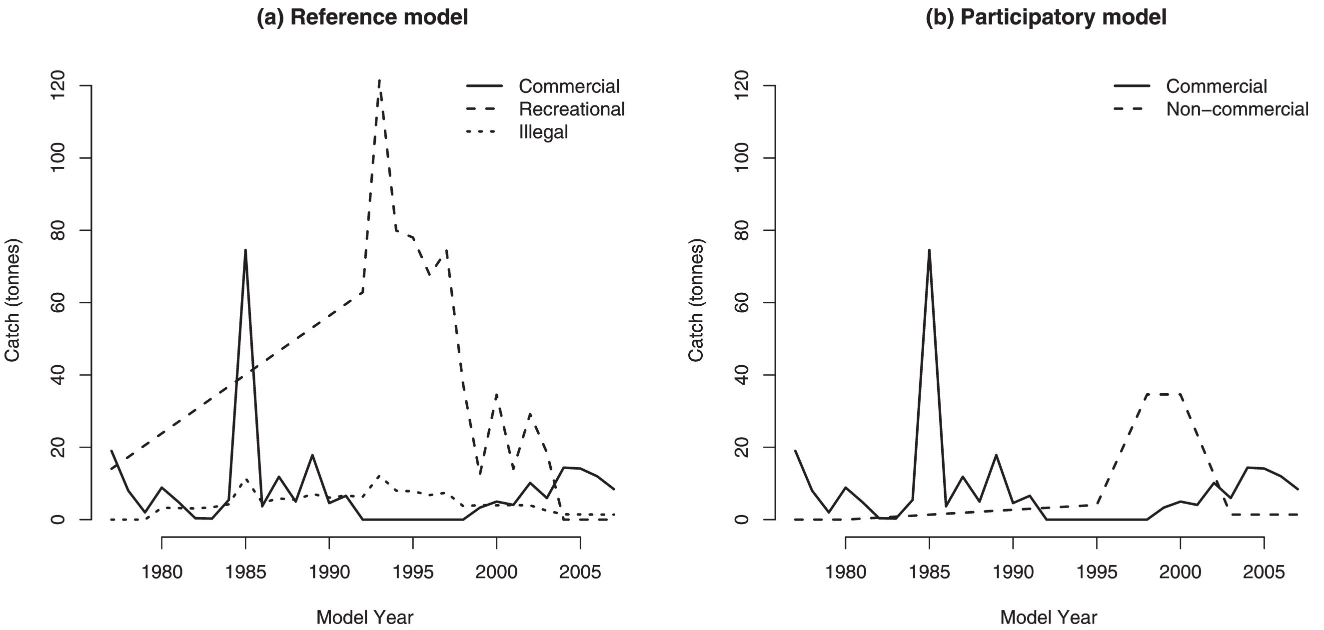

Fig. 1. Catch series for abalone: Zone E. (**a**) Commerical, Recreational and Illegal catch values (as given in Table 2) input into the Reference model. (**b**) Commercial catch values input into the Participatory model with Non-Commercial catches estimated during the model fit.

given parameter θ and its maximum likelihood estimate $\hat{\theta}$, $\Lambda = 2[lnL(\hat{\theta}) - lnL(\theta)]$ follows a χ^2 distribution with one degree of freedom. This allows confidence intervals to be approximated numerically by finding θ, so that Λ equals the required (95%) quantile of the χ^2 distribution.

In order to compare the Reference model (Equation 1) currently used in the stock assessment with the Participatory model (Equation 5) presented here, model goodness of fit was measured using the Akaike Information Criterion.[18] This is calculated as $AIC = -2lnL + 2p$ where p is the number of parameters estimated (four for the Reference model and a maximum of eight for the Participatory model). The model with the lowest *AIC* is considered to be the best representation of the data.

To compare the implications of model predictions for management of the abalone resource, both the biomass B and replacement yield RY for 2008 are reported. The replacement yield for year n for the Reference model is given by:

$$RY_n = rB_n\left(1-\frac{B_n}{K}\right) - R_n - P_n \qquad (6)$$

and represents the maximum sustainable commercial catch for that year. For the Participatory model, $\widetilde{P}_n$ is used instead of R_n and P_n in Equation (6).

Biomass projections

Biomass projections are presented for each zone up to 2020 assuming an unchanged TAC. Current TAC values are listed in Tables 2 and 3. Estimated Non-Commerical catches were assumed to be unchanged during the projection period (i.e. equal to $\widetilde{P}_{2007}$).

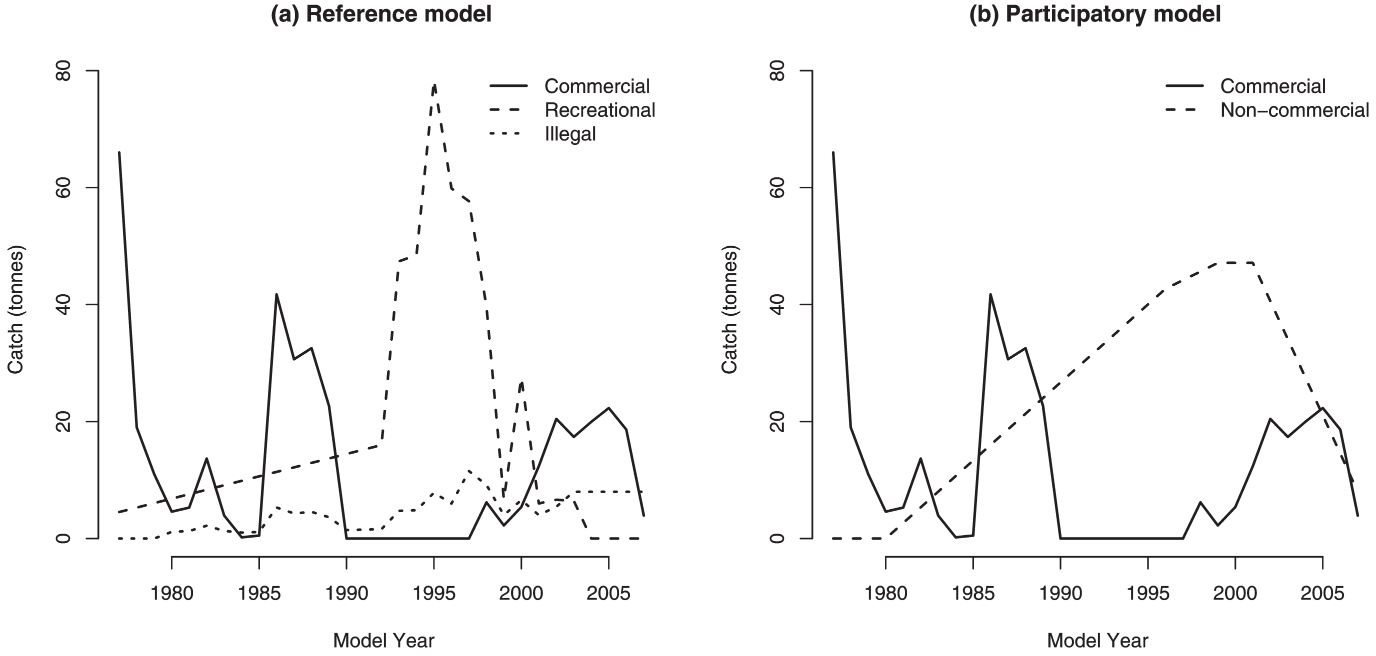

Fig. 2. Catch series for abalone: Zone G. (**a**) Commerical, Recreational and Illegal catch values (as given in Table 3) input into the Reference model. (**b**) Commercial catch values input into the Participatory model with Non-Commercial catches estimated during the model fit.

Table 2. GLM-standardized CPUE (in kg/min), and Commerical, Recreational, and Illegal catches (in tonnes) for abalone: Zone E. The number of datapoints (*n*) used to calculate the CPUE index for each year is given. There were too few datapoints to calculate a reliable CPUE index for years 1982 and 1983. No Commercial catch data are available for 1998.

Model year	TAC	CPUE *n*	CPUE (kg/min)	Comm. catch	Rec. catch	Illegal catch
1977				19	14.1	0
1978				8	17.3	0
1979				2	20.6	0
1980		19	1.38	8.9	23.8	3.3
1981		8	1.42	4.9	27.1	3.2
1982		2	–	0.4	30.3	3.1
1983		1	–	0.3	33.6	3.4
1984		8	1.64	5.4	36.8	4.2
1985		160	1.44	74.6	40.1	11.5
1986		9	1.43	3.7	43.3	4.7
1987	20	43	1.23	11.8	46.6	5.8
1988	20	16	1.18	5	49.8	5.5
1989	20	42	1.32	17.8	53.1	7.1
1990	20	19	1.09	4.6	56.4	6.1
1991	10	42	1.04	6.6	59.6	6.6
1992	0			0	62.9	6.3
1993	0			0	121.4	12.1
1994	0			0	79.9	8
1995	0			0	78	7.8
1996	0			0	67.6	6.8
1997	0			0	74.5	7.4
1998	5		–	–	37.2	3.7
1999	5	25	1.11	3.3	12.4	4
2000	5	32	1.08	5	34.5	3.9
2001	5.3	28	0.98	4.1	14	4
2002	13	73	0.77	10.1	29.2	3.9
2003	13	43	0.86	6	18.5	2.4
2004	15	141	0.78	14.4	0	1.4
2005	15	132	0.76	14.1	0	1.4
2006	12	114	0.79	12	0	1.4
2007	12	70	0.89	8.4	0	1.4

Results

The results of each model fit are given in Tables 4 and 5. For both zones it was found that the Participatory model provided a better explanation of the data (as indicated by the *AIC*), giving markedly different biomass predictions in comparison with the Reference model (Figs 3b and 4b).

Table 3. GLM-standardized CPUE (in kg/min), and Commerical, Recreational and Illegal catches (in tonnes) for abalone: Zone G. The number of datapoints (*n*) used to calculate the CPUE index for each year is given. There were too few datapoints to calculate a reliable CPUE index for years 1984 and 1985.

Model year	TAC	CPUE *n*	CPUE (kg/min)	Comm. catch	Rec. catch	Illegal catch
1977				66.0	4.5	0.0
1978				19.0	5.3	0.0
1979				11.0	6.1	0.0
1980		9	1.37	4.6	6.8	1.1
1981		11	1.54	5.3	7.6	1.3
1982		18	1.5	13.7	8.3	2.2
1983		9	1.24	3.9	9.1	1.3
1984		1		0.2	9.9	1.0
1985		1		0.5	10.6	1.1
1986		89	1.43	41.7	11.4	5.3
1987	30	76	1.41	30.7	12.2	4.3
1988	30	95	1.26	32.5	12.9	4.5
1989	30	99	1.16	22.7	13.7	3.6
1990	0			0.0	14.5	1.4
1991	0			0.0	15.2	1.5
1992	0			0.0	16.0	1.6
1993	0			0.0	47.4	4.7
1994	0			0.0	48.5	4.8
1995	0			0.0	78.3	7.8
1996	0			0.0	59.9	6.0
1997	0			0.0	57.7	11.5
1998	15	91	0.98	6.2	39.7	9.2
1999	15	17	1.23	2.2	6.7	4.0
2000	15	39	0.92	5.4	27.5	6.6
2001	15	98	0.84	12.4	6.0	4.0
2002	25.5	109	0.99	20.5	6.6	5.4
2003	25	118	1.01	17.4	6.4	8.0
2004	27	152	0.79	19.9	0.0	8.0
2005	27	175	0.76	22.3	0.0	8.0
2006	22	155	0.78	18.6	0.0	8.0
2007	18	59	0.88	3.9	0.0	8.0

Zone E

For the Reference model, initial estimates of r were unrealistically small, and it was necessary to fix r during estimation of K and σ. Values of $r = 0.1$ and $r = 0.2$ were chosen on the grounds of previous work,[19] although it was found that $r = 0.1$ gave a superior model fit (as indicated by the *AIC*). The results assum-

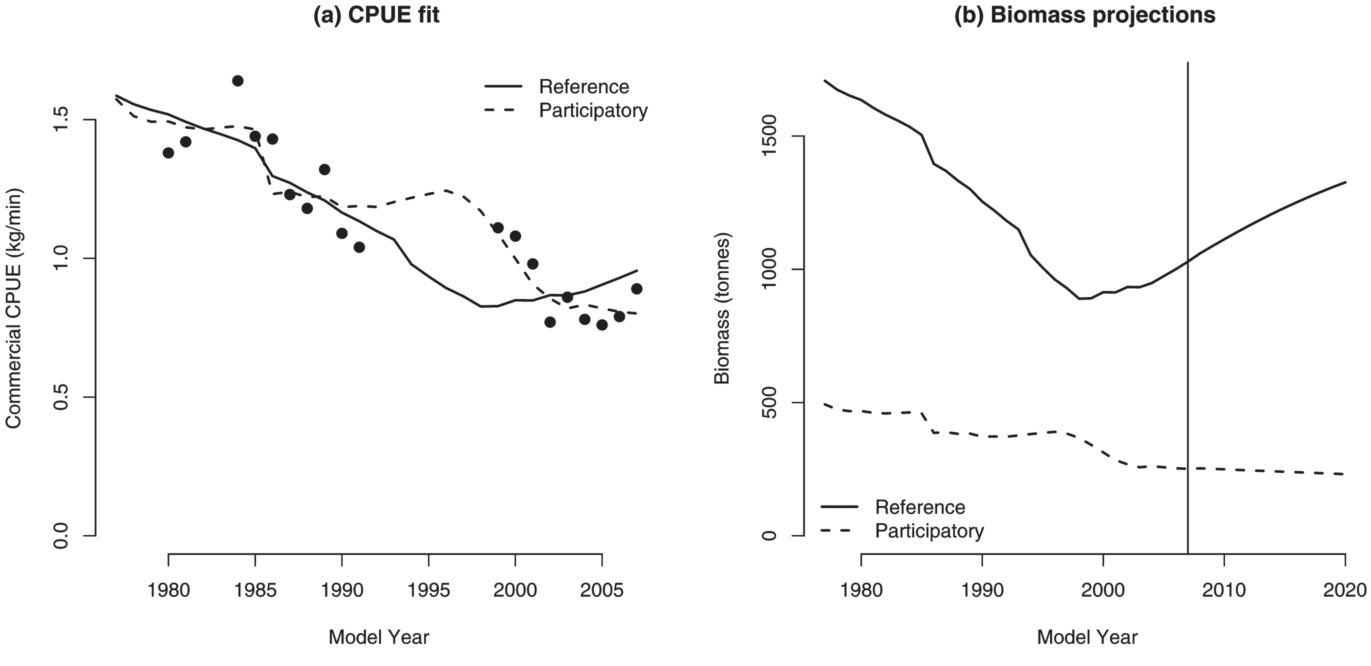

Fig. 3. Model outputs: Zone E. (**a**) Fit of Participatory and Reference models to standardized CPUE data. (**b**) Biomass projections for Participatory and Reference models. The vertical line indicates the start of the projection period in model year 2007.

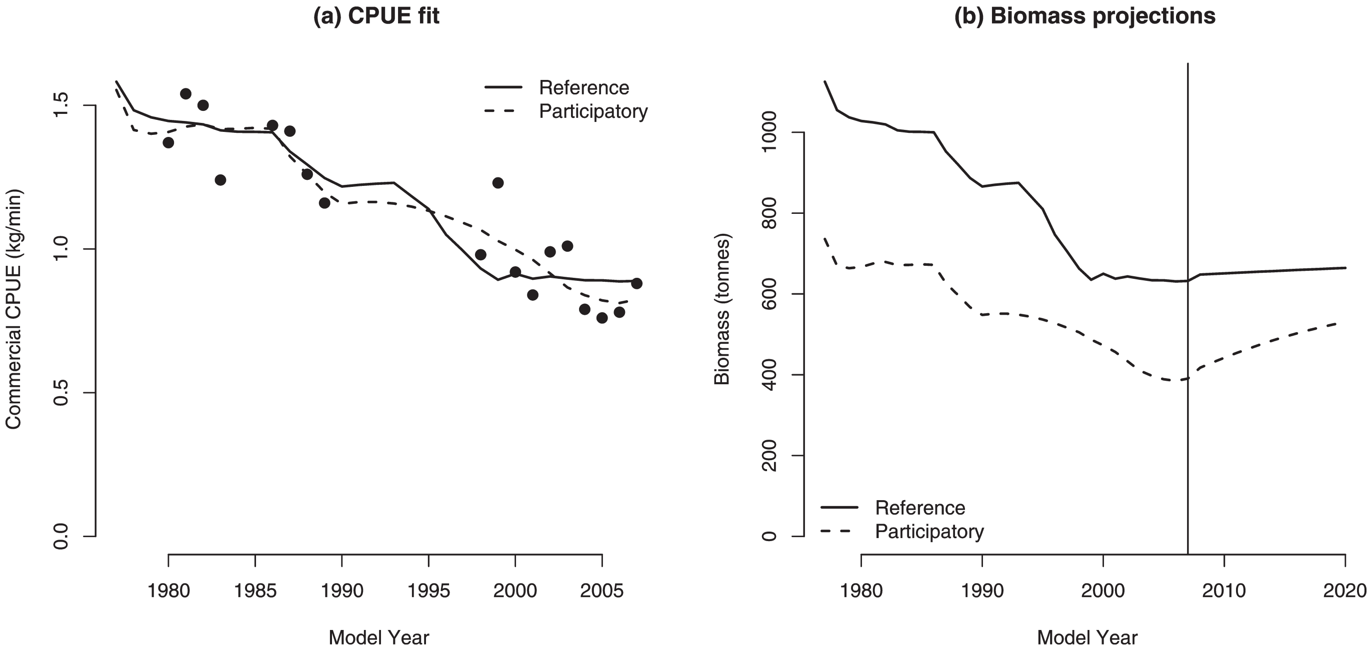

Fig. 4. Model outputs: Zone G. (**a**) Fit of Participatory and Reference models to standardized CPUE data. (**b**) Biomass projections for Participatory and Reference models. The vertical line indicates the start of the projection period in model year 2007.

ing $r = 0.1$ are therefore presented. When fitting the Participatory model, examination of the profile likelihoods for $\tilde{P}_{1977:1980}$ and $\tilde{P}_{2003:2007}$ revealed there to be very little information for estimation of their values (i.e. changes in $\tilde{P}_{1977:1980}$ and $\tilde{P}_{2003:2007}$ had little impact on the likelihood). $\tilde{P}_{1977:1980}$ and $\tilde{P}_{2003:2007}$ were therefore fixed at 0.0 and 1.4 tonnes, respectively, the latter being the illegal catch currently agreed upon by the Abalone Scientific Working Group (Table 2).

Fit of the Reference model was poor (Fig. 3a), and the Participatory model gave a markedly improved *AIC* (Table 4), providing a better representation of the CPUE series in recent years (Fig. 3a). It is notable that estimates of K and B_{2008} are substantially smaller for the Participatory model, consistent with estimated catches, which are much smaller than those assumed by the Reference model (Fig. 1). It is also noticeable that the biomass trend predicted by the Participatory model is less optimistic about the resource and its potential for recovery (Fig. 3b), with the estimated replacement yield for 2008 only about a quarter of that predicted by the Reference model.

Zone G

Analysis of the data from Zone G followed a similar rationale as Zone E. For the Reference model, r was fixed at $r = 0.1$. For the Participatory model, values of $\tilde{P}_{1977:1980}$ and $\tilde{P}_{2007}$ were also fixed at 0.0 and 8.0 tonnes, respectively, the latter value again reflecting the currently agreed upon illegal catch for Zone G (Table 3).

Poor fit of the Reference model is most noticeable for recent years (Fig. 4a) and the Participatory model produced an improved representation of the data (Table 5), although the small difference in *AIC* values suggests this improvement to be slight. The total biomass in Zone G is likely to be overestimated by the Reference model, being about 50% greater than that given by the better-fitting Participatory model. The Participatory model also suggests that the resource in Zone G is recovering, giving a

Table 4. Model outputs: Zone E. Maximum likelihood estimates and 95% confidence intervals based upon likelihood profiles are given. Biomass and catch estimates are given in tonnes, and q in 10^{-6} per minute. Values fixed on input are shown in bold.

	Reference model		Participatory model	
	Estimate	C. I.	Estimate	C. I.
K	1710	(1530, 2040)	493	(305, 1262)
r	**0.10**	–	0.09	(0.00, 0.20)
q	0.93	–	3.19	–
σ	0.130	(0.097, 0.186)	0.080	(0.060, 0.114)
$P_{1977:1980}$	–	–	**0.0**	–
$\tilde{P}_{1995}$	–	–	4.1	(0.0, 21.4)
$\tilde{P}_{1998:2000}$	–	–	34.6	(12.6, 71.8)
$P_{2003:2007}$	–	–	**1.4**	–
B_{2008}	1060	–	253	–
RY_{2008}	38.8	–	10.2	–
$-\ln L$	–29.3	–	–38.6	–
p	3	–	6	–
AIC	–52.6	–	–65.2	–

Table 5. Model outputs: Zone G. Maximum likelihood estimates and 95% confidence intervals based upon likelihood profiles are given. Biomass and catch estimates are given in tonnes, and q in 10^{-6} per minute. Values fixed on input are shown in bold.

	Reference model		Participatory model	
	Estimate	C. I.	Estimate	C. I.
K	1130	(1010, 1330)	736	(519, 5891)
r	**0.10**	–	0.21	(0.10, 0.53)
q	1.41		2.11	
σ	0.111	(0.082, 0.161)	0.089	(0.066, 0.129)
$P_{1977:1980}$	–	–	**0.0**	–
P_{1996}	–	–	42.7	(6.9, 96.9)
$\tilde{P}_{1999:2000}$	–	–	47.1	(0.0, 137.4)
$\tilde{P}_{2007}$	–	–	**8.0**	–
B_{2008}	648	–	418	–
RY_{2008}	19.5	–	30.4	–
–lnL	–30.5	–	–34.6	–
p	3	–	6	–
AIC	–55.0	–	–57.2	–

higher replacement yield (Table 5) and more optimistic biomass projections (Fig. 4b).

Discussion

Modelling of population dynamics is an invaluable tool for resource management. However, its usefulness is dependent on the quality of the data. For the South African abalone, data on IUU catches are particularly poor despite the high levels of illegal fishing impacting the resource.[3,20–23] Here we have shown that a participatory approach to stock assessment, which aims to address such unavoidable data deficiencies, can lead to an improved understanding of resource dynamics. Focus was restricted to a limited subsection of the South African abalone population, noting that there is even more intensive poaching in some of the other zones, and sophisticated methods for quantifying this have had to be developed.[23]

The combined Recreational and Illegal catch was estimated by fitting a logistic 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 for this Non-Commercial catch trend. It was established *a priori* (through the stakeholder interviews) that these trends were likely to provide a reasonable reflection of actual catches. The improved model fits resulting from this approach can therefore be justified as largely consistent with available information.

It is notable that biomass predictions from the Participatory model fits are markedly different to those from the Reference models. For both zones the total biomass estimated by the Participatory model is much less than that given by the Reference model. Furthermore, predictions regarding resource recovery are model dependent. The improved Participatory model fit for Zone E provides strong evidence for a downward resource trajectory, suggesting that the harvesting of abalone populations in this zone is above the sustainable level. This contrasts with the more optimistic outlook given by the Reference model. For Zone G the converse is true. Although evidence in this case is much weaker, improved fits for the Participatory model suggest that the resource may be recovering, whereas the Reference model indicates a flat future trajectory.

This implementation of a Participatory model to assess status of the South African abalone resource revealed it to be a fruitful complement to the standard modelling approach. It also had the additional benefit of furthering stakeholder inclusion in the management process, with potential benefits for compliance.[12] Co-management practices (in which stakeholders are closely involved in management of the resource) have been upheld as solutions to reducing the overexploitation of many Latin American benthic shellfish stocks,[24–26] where traditional top-down management has failed. This is consistent with an increasing recognition that the most successful fisheries management strategies are those that award long-term property rights,[27] a principle embodied by the individually transferable quota (ITQ) and territorial user rights in fisheries (TURF) management systems.[27–29] These systems are intended to confer a sense of ownership to the fishers and therefore provide an incentive toward sustainability.

In response to escalating poaching, the South African government allocated long-term (10-year) commercial fishing rights in 2003 and announced a new policy to underpin the allocation process.[30] Although this policy was intended as a TURF system, in which fishers are allocated rights to exploit their own locally fished areas, its efficacy was undermined by the granting of access rights to members of spatially (and socially) disjoint communities (M. Hauck, pers. comm.). This negated the principles of ownership and exclusivity intended to foster compliance within each TURF. Despite broadening of access to fishing among previously disadvantaged communities under the Marine Living Resources Act (1998),[31] and creation in 2001 of a limited commercial sector for small-scale operations (which in 2004 had 29% of the total TAC allocation[32]), many traditional fishers have failed to gain access to fishing rights.[12,31,33] Furthermore, TAC cuts mean that the economic viability of existing quotas is in decline. The incentive to poach illegally has thus remained high,[12] with drastic consequences for the long-term commercial viability of the fishery.

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Biomathematics in Africa (*continued from page 172*)

The paper by Lett and Mirabet reviews the state of the art in the modelling of motion in animal groups (page 192). The currently dominant approach is simply to simulate a very large number of individuals, and the focus of the research is the model of individual motion. Of particular interest is the effect of nearby individuals. The authors show that very realistic group motions emerge from very simple individual rules.

The paper by Welte illustrates the extreme difficulties presented by the various time scales in the HIV/AIDS pandemic (page 199). Treatment depends on time since infection, and planning depends on a reasonably good understanding of how many people have been 'recently infected'. The author shows that using both RNA and antibody test results allows reliable estimates, but then points out that this is not practical in the foreseeable future in South Africa. Mathematically, the difficulty is due to the extremely short 'window period' (interval between infection and its detectability) of these highly sensitive tests. Paradoxically, a less sensitive test with a longer window period is needed for estimating the population size of 'recently infected' patients. Of course, the more sensitive tests are still necessary, as they are best for individual treatment.

Age is important in biology, as it is perhaps impolite to remind some of our readers. The simplest approach is to consider a small number of age classes, as in the classical Leslie matrix. Moussaoui *et al.* extend this to space by considering two patches, and obtain a useful, if crude, characterization of ecotoxicity: that if one patch is sufficiently polluted, the population will go extinct in both (page 203).

Perrier and Laurie describe a technique for spatial data analysis (page 209). Multifractals have been of interest in a number of environmental sciences for some years, and the Rényi dimensions $D(q)$ are frequently used in describing them. What Perrier and Laurie provide is a simple way to estimate Rényi dimensions directly from density data.

Ouifki *et al.* is another contribution to the slowly emerging understanding of the HIV/AIDS pandemic and its management (page 216). Presumably because time scales are broadly similar, there is strong coupling of the various population dynamics: the virus within a host, the virus among the host population, and the host population itself. In this complex setting, careful modelling may well be crucial to humanity's eventual mastery of the disease; Ouifki and his colleagues explore the within-host dynamics of a simple model under a variety of treatment options. ❑